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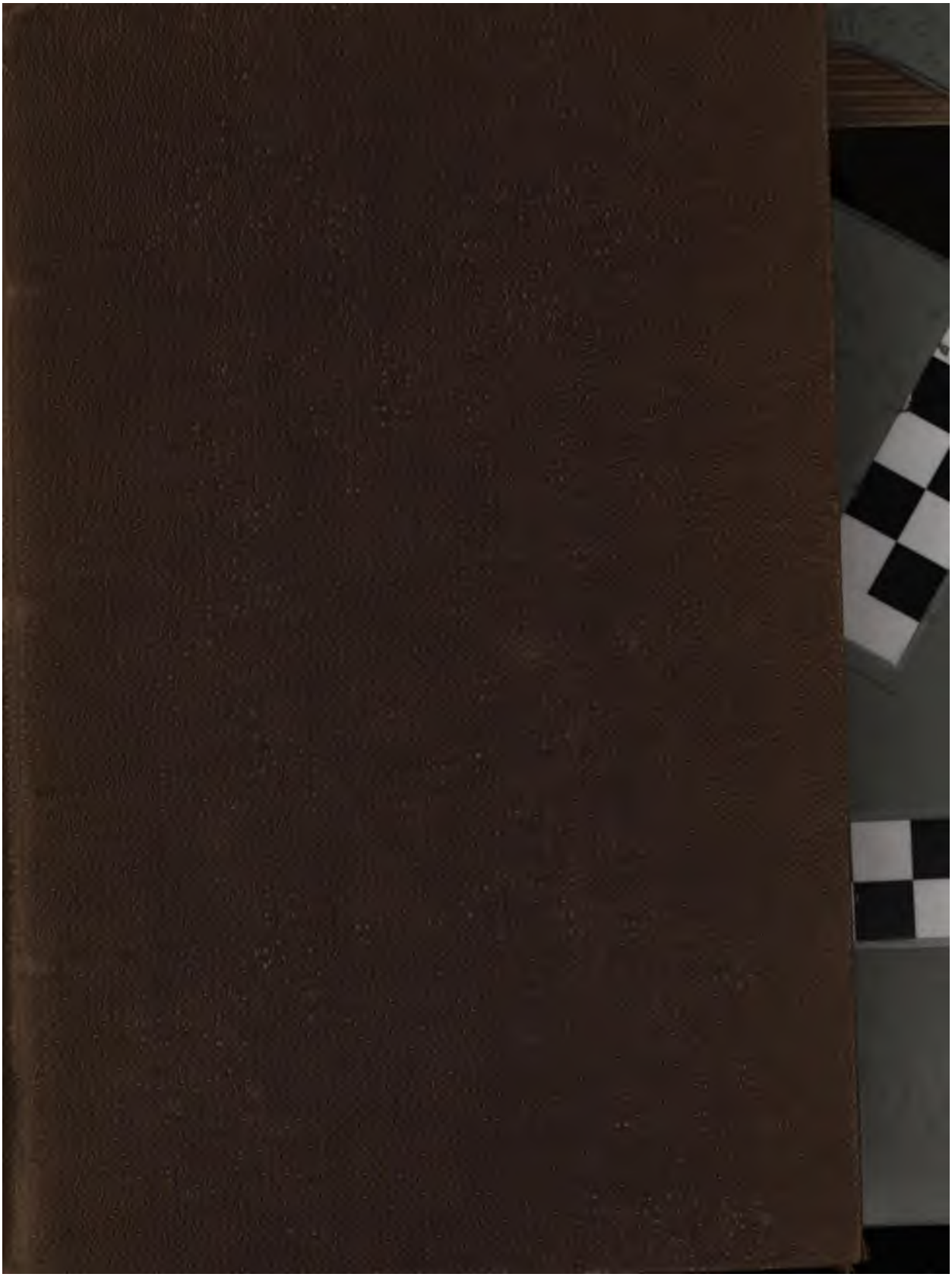

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1882-83.

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PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

EIGHTIETH SESSION, 1882-83.

I.—*On Insensibility arising from a Deficiency of Oxygen in the Air.* By Dr. WALLACE, President.

[Read before the Society, 15th November, 1882.]

THE evil effects of breathing the air of crowded apartments were formerly ascribed to the existence in such air of an abnormal quantity of carbon dioxide, usually called carbonic acid gas, which was stated to be a deadly poison; but the views of chemists and physiologists in regard to this have been much modified of late years, and some authorities have gone so far as to express the opinion that it is not a poison at all, in the ordinary sense of the word. A little consideration will show that the effects resulting from breathing the air of a confined and overcrowded apartment cannot be due exclusively, or even chiefly, to the presence of carbonic acid gas; for that gas, as well as the aqueous vapour of the breath, is formed at the expense of the oxygen of the air, which diminishes in constant ratio to the increase of the products of the combustion of our food. For every per cent. of carbonic acid gas produced, there is a little more than 1 per cent. of oxygen taken up. Allowing, then, that carbonic acid is to some extent detrimental to the system when breathed, the effects to which I have referred are, at least partly, due to the diminished proportion of oxygen; and there is the further complication of an atmosphere saturated with aqueous vapour, and contaminated with the undefined volatile organic emanations from skin and lungs, which give a peculiar and oppressive feeling of "closeness" to the overcrowded and unventilated room. I think, however,

that physiologists are now agreed that the lethargy, amounting in extreme cases to coma, produced by breathing such air, results from deficient oxygenation of the blood; and it is a fair inference that the most important factor in the phenomenon is the lessened proportion of oxygen. The normal proportion of that gas is from 20·9 to 21 per cent. of the air when freed from aqueous vapour; and Dr. Angus Smith has shown conclusively that this proportion cannot be altered, even to the extent of $\frac{1}{4}$ per cent., without producing appreciable effects, while a loss of $\frac{1}{2}$ per cent. gives rise to serious inconvenience, and air containing only 20 per cent. of oxygen may produce grave consequences if breathed for a considerable time. On the other hand, a man can breathe, for a short time, an atmosphere containing only 16 per cent. of oxygen and about 4 per cent. of carbonic acid gas. When the deficiency of oxygen exceeds this to a sensible extent a candle refuses to burn, and a man exposed to it is speedily overcome and becomes insensible.

In all ordinary instances of this kind there are the complications I have spoken of, and I have thought the Society would be interested in a case which came under my notice about six months since, in which there are no such complications.

In the construction of a railway bridge over the Forth, near Alloa, a number of iron cylinders were sunk in sections or rings of 6 feet diameter and several feet in height, and making up in all, when finished, about 60 feet. I will not go into the mechanical details of the construction of the cylinders, except in so far as to say, that the sections were placed one on the top of the other in such a way that a rather wide space was left all round, which had to be filled up from the inside with a rusting composition, well known to engineers, composed of iron turnings mixed with a small quantity of flowers of sulphur, with the addition, in some cases, of a little powdered sal-ammoniac. This mixture, when wetted with water, soon oxidizes and swells up so as to completely fill up the spaces into which it is thrust. At the Alloa bridge a considerable number of the cylinders had been erected—the most of the "rusting" having been done by one man, who mixed up the composition with water in a pail and applied it to the joints without being affected by it to any appreciable extent. On one day, however, I think about the beginning of May, when there was a perfectly still, somewhat hazy atmosphere, and considerable heat without direct sunshine, this man was observed to become overpowered by some mysterious influence,

and a companion descended by a windlass on the top to bring him up. He managed to get him propped up in the bucket, in which he was pulled up to the fresh air, when he soon revived; but his deliverer was in turn overpowered, and, falling back into a pool of water at the bottom of the cylinder, was drowned. One of the contractors now descended, taking care to fasten a rope to his body in case he too might be rendered insensible by the noxious gas, which was now supposed to be present at the bottom of the cylinder; and fortunately so, for he speedily succumbed and was immediately pulled up by the rope.

On being consulted regarding this apparently mysterious occurrence, I at once saw that the theory of an accumulation of carbonic acid or other noxious gas at the bottom of the cylinder was untenable, for the bottom was covered with water, and no gas could have come up from the bed of the river without being seen bubbling through the water. A few experiments with the rusting composition, a quantity of which was supplied to me, clearly showed that it absorbed oxygen from the air with great rapidity, so that in one of my experiments a portion of air was deprived of its oxygen in ten minutes to such an extent that it would no longer support the combustion of a candle, and in two hours 16 per cent. was absorbed. In another case, continued for a longer period, a loss of $20\frac{1}{2}$ per cent. occurred, or nearly the whole of the oxygen. At the same time the mixture became very warm, the temperature in one case rising to 156·° Fahr., while the iron oxidized and the mixture acquired a brown colour. I had no hesitation, therefore, in ascribing the accident to the absorption of the oxygen of the air in the cylinder by the rusting composition, coupled with the peculiar condition of the atmosphere, which, while it favoured chemical action between the oxygen and the iron and sulphur in the mixture, prevented the circulation of the air in the cylinder, which usually took place to a sufficient extent to prevent serious consequences. The deadly gas at the bottom of the cylinder was therefore nothing more nor less than the nitrogen which constitutes four-fifths of the bulk of our atmosphere, but which, deprived of its companion oxygen, is entirely unable to support respiration. We have in this unfortunate occurrence, by which one life was lost and others endangered, a justification of the German name of nitrogen, stickstoff—which may be freely translated choke-stuff or choke-damp—a name which in our language is applied exclusively to carbonic acid gas.

II.—*On Technical Education.* By DAVID SANDEMAN and E. M. DIXON, B.Sc.

[Read before the Society, 6th December, 1882.]

APART from the fact that three years have elapsed since a paper has been brought before this Society upon the question of communicating to young persons the peculiar kind of knowledge which it fosters and disseminates, the time seems to have arrived for the Society to consider how its educational functions are likely to be affected by the recent acts of the Legislature. We therefore have thought that a paper discussing the relations of the school to the workshop would at present lead, at least, to a useful discussion of the question, and that we might also, by such a paper, put before this Society an opportunity of making its voice heard by the various educational bodies that are now interested in the Royal Commissions that have been respectively charged with the investigation of the condition of technical education at home and abroad, and with the rearrangement of the educational endowments that are generally believed to be now yielding only partially satisfactory results. At all events, we intend to consider the question that gives the title to the present communication in the light of the duties that have been assigned to the two Commissions named.

That the efficient management of any industry requires the combination of many talents and of much knowledge is a truism that never required serious discussion. The advocate of technical education is, we believe, quite equalled in the recognition of that fact by those who believe that it is a passing whim, which will disturb the business world more or less for a season, and finally be relegated to the limbo that has already received many other insufficient remedies for social ills. The question that is really agitating manufacturers and legislators is not whether our industrial prosperity demands from those who conduct these industries much

skill and many talents, but what is the way in which the necessary skill can be secured? In seeking for an answer to that question, some turn to the workshop and others to the school; and we therefore believe some good may be done if we are fortunate enough in this communication to throw even a little light upon the respective functions of these two institutions, and on the relation in which they either actually do stand or ought to stand towards each other.

Now, for practical purposes it is not necessary to attempt to define with faultless logic the precise functions of the school and the workshop; the ordinary understanding as to the distinction between them is quite suitable for our purpose. That understanding is that the function of the school is to teach, and the function of the workshop is to execute work. On the other hand, a place in which manual work is taught, but where it is not practiced in the ordinary way of business, we shall call a school-workshop. In this broad sense we shall use these terms throughout the present paper.

On this understanding, then, we shall, in the first place, consider the sphere of action of the Elementary School and the relation in which it stands to the workshop, pointing out, at the same time, the attempts that are being made at present to bring them, in the case of certain trades, into closer union than has hitherto existed.

I.

An elementary school is one that carries on the systematic education of children to the point that may be reached by those of good average intelligence at about their thirteenth year. The subjects that form the intellectual nutriment of the pupils of such schools may be said to consist of English grammar, geography, history, and arithmetic, with some notions of geometry acquired by using drawing instruments, a few rudimentary conceptions of science in some cases, and a slight smattering of the grammar of Latin or French in others. It is not the business of this paper to criticise the methods whereby this range of subjects is attempted to be brought within the compass of the comparatively early age at which the pupils generally leave elementary schools; but it may be said, without implying the slightest condemnation of our educational methods, that when such a programme of study has to be gone over in so short a

space of time, we need not be surprised that the faculty of the pupils that is generally found to have received most development is the faculty of memory, and that their power of *thinking* seems, in very many cases, to have scarcely been awakened. We do not assert that the *reasoning* power of children of thirteen years of age could, as a rule, by any programme of study, or by any method of education, be otherwise than in a comparatively rudimentary state. We know that age is, with other things, requisite for the development of the reasoning powers. We simply seek to make it clear that, notwithstanding the great benefits that have come, and are unquestionably still to come, from the adoption of a national system of elementary education, the fact remains that the great mass of the pupils of elementary schools must of necessity leave school with their reasoning faculties still comparatively undeveloped, and that this fact is the more likely to be true of a larger proportion of the youthful population of the country just as the course of study is rendered more and more mechanical. We think that, in the case of children whose education must to all intents and purposes terminate at about thirteen years of age, special pains should be bestowed on training them to think, as far as their age will permit, and on keeping out of their programme of study all subjects that cannot be carried within their school-years to a moderate degree of completeness. Concentration, rather than expansion, should be the watchword of the elementary school, and it should be remembered that pupils are much more likely to leave school with a desire to add to the information they may have there received, when they acquire that information through the exercise of their reason, than when they merely carry it about for a time in their memory. If these principles are not as yet found to be very generally or very fully recognized in the management of the elementary schools of this country, we believe that the explanation chiefly lies in the absence of an organized system of secondary education, whereby the elementary school is, for the time at least, compelled to expand its curriculum unduly, and to attempt the teaching of subjects that it is unable to deal with satisfactorily. We think that the great educational want now existing is a well-organized set of secondary schools; and our opinion is that until a sufficiency of such schools has been for some time in operation neither the elementary school, on the one hand, nor the technical school on the other, will be able to assume its proper position. We therefore hope that the Commissioners, who have now,

practically, in their hands the Scotch educational endowments, will find themselves — after providing for elementary education according to the founders' intentions—in possession of the means of instituting at least the nucleus of a system of secondary education.

Turning now to the workshop, we have to see the steps whereby the pupil of the elementary school rises to the position of a workman; but, as this part of our subject has been recently handled by many writers of large experience both in trade and in education, it is unnecessary for us to dwell long upon it. The point on which we desire chiefly to concentrate attention is the fact that, in many industries at least, so little attention is now given to the training of the youthful apprentice that the first two years of his apprenticeship are, in great measure, wasted. We are aware that the age at which boys begin their apprenticeship is, as a rule, such as to prevent the possibility of their learning much of their trade for two years after they leave school, but we insist that this evil is greatly intensified by the want of a serious effort to instruct apprentices in their craft. We do not mean to convey by these remarks any charge of breach of faith on the part of employers towards their apprentices. The cause, as we think, has a deeper root than that. We believe that the old form of apprenticeship—which, so far as the production of intelligent craftsmen was concerned, was unquestionably superior to the form that has recently taken its place—is gone with many other things of the past, never to return. The world's work is now carried on in all sorts of ways differently from that in which it moved in what we all are disposed to call the good old times. Division of labour has been pushed, within the last half century, to an extent not previously thought of, and out of that alone have come many consequences that have already involved a complicated series of social adjustments. The real root, perhaps, of all the leading social changes in our day is to be found in the application of the steam-engine to the purposes of locomotion and of manufacture; but the advantages that have come from these applications are so vast, that all mankind is willing to purchase them, even at the expense of much trouble to discover the social readjustments that have become thereby inevitable. What are to be our modern methods of general as well as of special education are now being eagerly discussed in all civilized countries; and certainly there can be no more important social question for a community, than the devising of

the best means of securing the greatest possible amount of intelligence on the part of the greatest possible number of its members. We think that the neglect of the apprentice is temporary, and that he will receive his due so soon as the question of teaching trades has been solved in a way that commands public approval.

Bearing in mind that we are considering, for the moment, the transformation of the average pupil of an elementary school into an ordinary workman, we now proceed to pass under review some experiments that are being made to prepare such boys to pass from the school to the workshop. We shall select, as our chief example, the now somewhat celebrated school in the Rue Tournefort, Paris. To this school attention has been drawn within the last two or three years by several educationists in this country, and it has also received special notice from the Royal Commissioners on Technical Education. As we shall see presently, it has been visited a few months ago by a deputation from the School Board of Manchester, which has reported in favour of somewhat similar experiments being made in two of the schools under that Board.

The idea underlying these experiments is that it is possible to teach the rudiments of practical workmanship to boys when at school, and so to prepare them for subsequently learning their trades better, and in a shorter time than can be done by the prevailing form of apprenticeship. In some cases a larger, and in other cases a smaller amount of practical instruction is being attempted, but still one common idea runs through all—viz., the possibility of combining with ordinary school work the teaching of the elements of practical workmanship. In the School already named—viz., the school of the Rue Tournefort in Paris—a considerable amount of the pupils' time is given to practical workmanship; and the attempt is there made to communicate to the pupils, who remain at school till they complete the curriculum of study, a very substantial amount of skill in the trade that they intend to follow. This attempt would appear to be very successful; but it is easy to see that, since the boys leave school at or about 13 years of age, it is impossible for them to acquire so much knowledge of practical workmanship except at the expense of their ordinary school education. This fact has caused the municipal authorities of Paris to restrict the amount of manual work in the elementary schools into which they have recently introduced it. With this restriction, the results obtained appear to be giving satisfaction,

if we may judge from the fact that manual work has been lately introduced into about fifty other elementary schools in Paris. The delegates from the School Board of Manchester have taken these lately instituted schools as their model, and the words of their Report referring to these schools may be here appropriately quoted:—

"After a careful examination of the processes of ordinary "instruction employed in the schools of Paris, we are not disposed "to recommend any changes in the methods which are in such "successful operation in our own Board Schools. . . . The two "features in which there is any fundamental difference, compared "with our schools, are:—

"1st. The introduction of 'manual instruction' into some of the "boys' schools, which, from its apparent success, is likely "to become general.

"2nd. The more general and methodical teaching of drawing in "the Schools, which gives an important training both to "hand and eye.

"The primary object of the manual instruction is to familiarize "the boys with the tools and instruments which are used in the "ordinary mechanical trades, to give them dexterity of hand, and "to bring them up in habits of industry. As a physical exercise "manual instruction is of importance, and forms a healthful and "agreeable variety to the course of intellectual training.

"The manual instruction is rendered more interesting and useful "by short lectures given each week on the nature of the various "kinds of wood and other materials employed. Thus specimens are "shown of the tree in its native state, and in its different forms, up "to some finished article. The boys are allowed to take home the "completed specimens of their work. The instruction in manual "labour does not interfere with the ordinary course of school work. "The time allotted to it is left to the discretion of the director, and "in the schools which we visited the hours for manual labour were "from 7 to 8.30 a.m., and from 4 to 5.30 p.m. At present only "boys of 12 years of age and upwards are allowed to go to the "workshops, and the attendance is voluntary; for the most part, "however, the boys show a decided taste for these school-work-"shops. It is in contemplation to make manual instruction com-"pulsory.

"We do not hesitate to recommend the Board to introduce into "one or two schools manual occupations, by way of experiment. "The schools we would suggest for this purpose are the Lancas- "terian, in Marshall Street, Oldham Road, and the Sharp Street "schools — the former having children of a somewhat superior "class, paying higher fees; the other situated in a poor locality, "at the lowest scale of fees. In these schools there is the needful "space, and the experiment can be made at a very slight cost."

With regard specially to the first school in Paris in which manual instruction was combined with ordinary elementary instruction—viz., the school in the Rue Tournefort—the Royal Commissioners on Technical Education make the following remarks:—

"This school was established on its present footing in 1873. "Until the beginning of last year trade instruction was commenced "at the age of ten years, and continued for three years. During "the first two years every child was taught drawing, modelling, "carving, joiners' work, and smiths' and fitters' work. In the "third year the work was specialized, some of the children being "taught modelling and carving, others joiners' work and cabinet "making, others again forging and fitting. Since the beginning of "last year the same plan has been continued, but, in addition, the "children in the lowest classes, beginning even at six years of age, "have three lessons of one hour each per week of the instruction "in handicrafts, which, until then, did not begin until they "had attained the age of ten years.

"Although, as has been said, the work is specialized in the last "year, the pupils engaged in modelling and carving return one "day in each week of that year to the joiner's bench and the "forge, the joiners and turners return to the forge and modelling, "and the smiths to modelling and joiners' work."

Such are some of the experiments that are being made to enable boys that are to become, for the most part, ordinary workmen to obtain a fair amount of general education, and to receive, while so doing, that preliminary training in workmanship which, at the early age at which they must leave school, is really indispensable, but with which they are inadequately provided in workshops as at present constituted. Nothing but actual experience can settle the question as to how far these experiments are on right lines, but

our personal opinion is that they will be successful if properly conducted, *and if nothing is attempted beyond communicating a knowledge of how to handle tools, and some skill in mechanical drawing.* All boys should, indeed, learn at least something regarding the use of tools, and every boy, moreover, is pleased to work with them. These two facts are powerful reasons for the introduction of manual instruction into all our schools, but especially into the schools that are attended by boys who, in the ordinary course of things, must become artisans. It seems to us, indeed, that instruction of this kind is so important, under the circumstances now existing, that the question should not be so much why should we introduce it into the programmes of our schools, as why should we exclude it? No doubt, the prevailing age of the pupils in our elementary schools causes difficulties that are not to be overcome without a serious desire and effort to overcome them; but the experiments that have so far been made encourage the hope that success is attainable.

II.

We now come to consider the case of secondary schools, with regard to the manner in which they either actually do or might prepare boys for industrial pursuits. We may say at the outset, that secondary schools differ from elementary schools in several respects, but that these differences have their root in the condition as to wealth which characterise the various strata of society. Speaking generally, men possessed of means desire their children to grow up well educated, and are sufficiently intelligent to know that this necessarily involves, among other things, that they should remain at school till at least their sixteenth year. We may, no doubt, admit that the great mass of men desire to see their children well educated, and that they keep them at school as long as their means enable them to do so. But higher education is, as a rule, within the reach of the wealthier classes only; and we cannot do much more than lament the fact that the world loses in thousands of cases the advantages it might otherwise have, if the natural abilities of every child were fully developed by education. Secondary schools, then, are, as a rule, schools for the education of the children of men who are superior as regards wealth to ordinary working men; and the pupils of such schools are, as a rule, kept under systematic instruction till at

least their sixteenth or seventeenth year, after which some proceed to mercantile pursuits, others learn a branch of manufacture, and others betake themselves to the so-called learned professions.

Now, in the organizing of schools of this class, the educationist is able to reckon upon having under instruction for some time boys of a certain degree of maturity of mind, and he can therefore introduce into his curriculum of study subjects not merely calculated to instruct his pupils, but also to call forth the higher intellectual faculty of thought. He has time and opportunity, indeed, sufficient to enable him to attend not only to the *general* education of his pupils, but also to take, in some cases, a few preparatory steps in the direction of their *professional* education. He will, however, carefully prevent the professional education from encroaching upon the general education, which is the great means of securing the harmonious development of the mental powers of his pupils; for he well knows that professional education is, strictly speaking, impossible to any pupil whose mind has not received the discipline of a general education embracing the development of all his faculties. Moreover, he will bear in mind the fact that the professional education he may be able to give should be directed to the preparing of his pupils for a higher position than that of the clerk or the working artisan.

Up to the present time, the subject to which the teacher has resorted for the purposes of general education has been principally the study of the ancient languages of Greece and Rome. Now, there is a growing disposition to have recourse to what some call "modern" subjects—*i.e.*, the study of modern languages, and a more extensive study of mathematics and the elements of natural science. Among educationists the comparative merits of these various studies have been for some time warmly contested, and while neither the "ancients" nor the "moderns" can be said to have been routed, the battle has apparently inclined to the "modern" side, though it is doubtful whether the reason of that advantage does not lie in the circumstances of the times rather than in the merits of their cause. We believe that the substance of all that has been said in favour of classical studies is correct, for the experience of civilized mankind for many generations seems to allow of no other explanation; but, on the other hand, we must demur to the *exclusive* claim that is sometimes made in favour of these studies—viz., that they develop the faculties of the mind better than any other

studies possibly can. We are disposed to think that the subject-matter is not the principal thing in education—that is to say, we believe that the mental discipline which a boy receives from the study of any subject does not depend so much upon the nature of the subject he studies as upon the way in which he studies it. However well suited the subject may be for developing his taste or strengthening his reasoning powers, no material benefit in an educational sense can result if he use it merely as an exercise of memory, and do not give to it the full play of his mind. It therefore appears to us that the classical languages are excellent for the education of some boys, indeed of most boys; but we believe at the same time that mathematics, modern languages, and natural science are all capable, if properly taught, of producing equally satisfactory educational results. In expressing this opinion we are quite aware that we are in opposition to a very large and a very powerful body of educationists, who, it must be conceded, have had good opportunities of comparing the results of training by means of the ancient languages, and by means of what we may shortly call modern subjects. We hold that the teaching of natural science in particular is, so far as schools are concerned, really in its infancy, and that the accumulated experience of perhaps several generations of teachers may be necessary to bring out fully the capabilities of natural science as a means of general education. An indispensable condition, however, is that such teaching be given by properly trained teachers provided with the necessary apparatus.

From these remarks it may be inferred that we favour the idea of instituting in this country three kinds of secondary schools, similar in their general features to the three kinds already existing in Germany. In one, the careful study of the classical languages would be the characteristic feature; in another, less attention would be given to ancient languages, and more to modern languages, mathematics, and natural science; and in the third, the study of the ancient languages would be entirely dropped, and the pupil's attention devoted to modern subjects. These three kinds of secondary schools already exist, as has been said, in Germany, and are there known by the names of *Gymnasium*, *Realschule*, and *Gewerbeschule* respectively. As one might anticipate, the *Gymnasium*, or classical school, is the oldest of the three, and the most numerous; and the *Gewerbeschule*, or non-classical school, is of very recent growth, and as yet the

least numerous. Still, the best educational opinion in Germany is, we believe, in favour of having all three, in order to meet fully the requirements of modern society. It is believed that all of them supply in reality a good general education, but that each is better suited than the others for pupils who are to follow particular professions. The non-classical type of secondary school is evidently the one that concerns us at present, for it has been specially designed to meet the requirements of pupils who are intended for industrial pursuits; and as we have now sufficiently indicated the general character of the education given in such a school, we will now proceed to consider how a pupil should pass from it into the workshop.

We believe there is no reason why a pupil of such a secondary school should not pass to the learning of his trade with a considerable amount of skill in practical workmanship acquired during the last two or three years spent in the school. For this purpose the school should, of course, be provided with the necessary appliances—that is to say, with a school workshop and a chemical laboratory.

As to the organizing of a school workshop for a secondary school, there does not appear to us to be so much difficulty as there is in connection with the organizing of shops for elementary schools. The more mature age, and the greater attainments of the pupils in theoretical subjects, give much greater freedom to the organizer of shops for secondary schools. But, as one of us has had experience of the actual organizing of such a shop, which may claim to be quite successful, and which is now serving as a model to the managers of other schools both at home and in the colonies, it may be the best way of treating of school workshops for secondary schools to leave generalities and theoretical speculations, and simply describe the development of the small workshop at present in operation in Glen's Institution in this city.

After the trustees of that institution had decided to apply the funds at their disposal for the promotion of secondary education among boys intended for industrial pursuits, and had appointed one of us to organize the institution on these lines, it was agreed to adopt the suggestion made by the head-master, that a chemical laboratory and a school workshop should, amongst other new buildings, be provided. This suggestion was based upon the fact that chemistry, on the one hand, and mechanics, on the other, form the basis of all, or nearly all the arts and manufactures. It was also considered that theoretical instruction in these subjects is insufficient

to enable a lad to master them, but that he requires, in addition, to have an opportunity of working upon them practically. This practical instruction was therefore regarded as essential to giving the pupils thorough command of what they learned in lectures or from books, and, so far, turning them out with a certain amount of scientific knowledge that was real to them, and which they saw their way, to a certain extent, to make practical use of in the arts. *There never was, nor has been, the least idea of attempting to teach the pupils a trade.* The whole object has hitherto been to prepare lads to learn, very efficiently, trades that have a mechanical or a chemical basis.

Now, besides starting with a clear conception of what was to be aimed at in such a workshop, it was, of course, necessary to find suitable men for giving the instruction, and to discover ways and means of allowing as many as a hundred boys to find useful employment without involving more than a moderate outlay of money for wood and other materials. The first difficulty was met by the appointment, as engineering master, of a gentleman who had held, for three years, one of Sir Joseph Whitworth's scholarships, and who necessarily had a good knowledge of engineering, both on its theoretical and on its practical side. To him was assigned, under the head-master, the duty of finding suitable employment for the pupils in the workshop, as well as of teaching the theoretical parts of his subject. Finally, as the institution grew, it was found that the presence of a good practical mechanic in the shop, during the regular school hours of every day, was necessary; and, a little over twelve months ago, such a person was provided by the trustees. This mechanic consults with the engineering master as to the work to be done by the boys, and, besides teaching the latter the best way of using their tools, and generally proceeding with the work they have to execute, he takes charge of the shop, in the way of seeing that discipline is maintained, tools put properly into the boys' tool-chests after their work is over, every boy's work kept untouched from one lesson to another, and so forth.

As regards the pupils, it may be said that, as a rule, their ages average about 14 years at the time they enter the workshop. Admission to the shop, however, is not determined by age, but by their progress in general education. To state the fact exactly, it may be said that the shop is first open to boys when they enter the third highest class in the school—that is to say, the time that

a pupil who passes through all the classes of the school has in the shop is three years. Only a comparatively small fraction of his time, however, is given during these years to the shop. In the first year he has only 2½ hours per week, in the second he has not more than 3 hours, and in the third year only 5 hours per week. The rest of his time is taken up chiefly with the study of such subjects as freehand drawing, practical solid geometry, as a foundation for technical drawing generally, machine construction or building construction and drawing, mathematics, theoretical and applied mechanics, physics, chemistry, both theoretical and practical, the steam-engine, and metallurgy. It is also to be noted that, in the last year, the pupils concentrate their attention either on engineering or on chemical studies, but that in the preceding years they all pass through the same course of study.

Referring specially to the work of a pupil in the shop during each of these three years, it may be said that in the first year he practices the use of carpenters' and turners' tools in the making of simple articles that he takes home, upon paying for the wood employed in their construction. The articles made are of a very miscellaneous description, small tool-chests, writing desks, stools, simple bookcases, &c., being among the most common. The articles to be made are very generally selected by the parents of the boys, but no boy is allowed to enter upon the making of any article till he has consulted the workshop instructor, who decides with a view to the suitability of the article for the boy's stage of progress. This arrangement exists, as has been said, for the first year that a boy spends in the workshop. We have now to see how he spends his second and his third year. By the commencement of his second year he has, of course, acquired some manual skill, and can undertake higher work. As to the exact amount of the skill acquired, it is not unlikely that many, who have only seen the work turned out by ordinary apprentices at the end of their first year of apprenticeship, would not be prepared for what can be done by the systematic instruction of boys for only 2½ hours per week. A boy of fair talents is, as a rule, found at the commencement of his second year in the shop to be quite able to begin with the construction of simple mechanical models from working drawings; and it may therefore be said shortly that a pupil's work for the second and third years consists in making models more or less complex, according to his ability, from scale drawings. We submit for inspection specimens of the work done by boys in each of these three

years, and we believe that an examination of these specimens will bear out our assertion that the work done by a boy receiving systematic instruction in practical workmanship during half a day in the week is, at the end of two years, not behind the work of a boy at the end of the second year of an ordinary apprenticeship in which he gives all his time to it. If we are correct in regard to this point, it is unnecessary for us to point out the great waste of valuable time that is going on in the engineering and other mechanical trades. *If, with regular and systematic teaching, all can be accomplished, for the first two years at least, in half a day per week that now occupies the whole time of an apprentice, there is a very serious loss of valuable time.* We say valuable, because he is of an age that enables him to learn very easily any subject that interests him. Would not the saving of this valuable time to apprentices in the mechanical arts, and their consequent higher education, tell in a few years upon our industries, and go far to enable us to cope with the best educated nations of the continent upon their own terms?

To sum up our views with regard to secondary schools and their relation to the workshop, we assert—

1. That secondary schools are the chief educational want of this country at the present time.
2. That, in order to meet the wants of the day, there should be at least two kinds of secondary schools, differing from each other in the prominence given by them to classical studies on the one hand, or to "modern" studies on the other.
3. That a secondary school, giving prominence to "modern" studies, is the best suited for the education of boys who are intended for industrial pursuits.
4. That a secondary school, preparing boys for the efficient learning of trades, should be supplied, with all the appliances requisite for teaching such scientific subjects that bear upon the arts, and that it should possess a well-equipped laboratory, and a school-workshop, provided with an adequate stock of lathes, benches, and tools.
5. That the instituting of such schools would greatly economise the time of apprentices, and that apprenticeships in some cases might, if otherwise desirable, be reduced to three years instead of five.

III.

We have now, in the last place, to consider briefly a class of schools that are really what we have been calling school-workshops, but which are often called technical schools. Their function is to teach, not principally to execute work. They are attended by pupils who have completed their school education, and who seek in them more thorough instruction in their trade than can be got in an actual workshop. The number of schools of this class is rapidly increasing in all countries, and it seems hazardous to say which trades cannot be well taught in this way. As trades differ greatly from each other as regards the facility with which something like a complete view of their methods and processes can be brought within a moderate compass, different methods of organizing these schools will, no doubt, be found to be necessary. The central fact is that systematic *teaching* is wanted, and that young men who, in the ordinary course of things, must rise to the positions of managers and foremen, now demand something better than the *laissez-faire* system of learning trades that exists in actual workshops. When this demand has grown to greater dimensions, and has invaded the trades generally, there is no doubt that the most suitable way of organizing a school-workshop in connection with each trade that requires it will be found. We think it is somewhat premature to lay down one plan of organization for all such schools. We think, besides, that the question where such schools are to be held is a mere matter of convenience. If it were found, for instance, that in one trade it is quite possible to bring within the compass of a building of moderate size an adequate supply of the tools and machines used in that trade, the question as to whether a school for the teaching of it should be held within the gates of a workshop wherein it is practiced, or in a special building, and not in connection with an actual work at all, is one to be decided by considerations of convenience. On the other hand, the teaching of some trades cannot, perhaps, be done justice to except in actual works; but the arrangements made within the gates of such works for the *bonâ-fide* teaching of the trade would constitute, quite as much as in the former case, a school-workshop or technical school. We think that such matters belong to details, and do not affect the essence of the question, which is simply this, Shall we have trades taught in a systematic way, or shall we allow them

to be learned in a haphazard manner, by lads who are left practically to do pretty much as they like or can? Schools of the kind to which we are at present referring have been, as yet, instituted in this country only in connection with the weaving and the dyeing trades, and with the chemical manufactures (for we include in the class of school that we are at present considering chemical laboratories devoted to the teaching of applied chemistry); but, on the Continent, especially in France, schools for the teaching of other trades than these have been in operation for some years. In Germany, the feeling has up to the present time been rather in favour of instituting schools of this kind, at least for the mechanical trades, in actual works; but Germany also contains some excellent schools, apart from works, for the teaching of everything relating to the textile industries. So far as schools for weaving, dyeing, and the chemical industries are concerned, there is now sufficient experience to warrant the assertion that they can be, under suitable conditions, perfectly successful. The fact that the number of them is steadily increasing in all the leading centres of the textile industry in this country is a good proof of their usefulness. At the present moment Belfast and Leicester are both providing themselves with weaving schools; and they have been in successful operation for several years in Bradford, Leeds, Huddersfield, Glasgow, &c. In the Yorkshire College of Science in Leeds there is also an excellent dyeing school, which is serving as a model to similar schools that are arising elsewhere. As to the Glasgow school for weaving, it may be pronounced to be one of the most successful schools of its class in the country; and its directors are now considering the means whereby they may add to its usefulness by the erection of a dyeing school.

Before terminating our discussion of schools in relation to the workshop, a word should be said regarding evening classes, to which peculiar importance is attached in Great Britain. These classes are either to supply young people who have left school very slenderly educated, even in elementary subjects, with an opportunity of repairing their deficiencies in these respects, or with supplying young men who are engaged in trades with information which they might have acquired had they been educated in a secondary school of the type that we have already recommended for those who aim at industrial pursuits. Evening schools cannot be expected to supply as satisfactorily as day schools the education

that is required in either case, if we consider the fact that the pupil has to give the most of his strength and time to his daily employment, and that he consequently has but a comparatively small modicum of either to devote to his evening studies; while, on the other hand, the pupils of day schools have their studies as their work and can therefore give to them all their strength and all their time. Still, under certain educational conditions, evening schools become a necessity; though we hold that the conditions which necessitate them should, as far as possible, be prevented. Just because the work of education can be carried on very much better in day than in evening schools, it is desirable that every young person should receive his education, both general and special, in a day school. But there is no prospect at present that the lower strata of the labouring population will be able to afford the price that must be paid for this advantage. *It is very important, however, that all who can afford to educate their children in day schools should do so*, though it must be remembered that even this is not to be expected till day schools exist capable of supplying freely the education that an industrial community requires.

The general conclusions to which this paper leads may be now finally summed up as follows:—

1. Every child should have, as liberally as the circumstances of his parents permit, a general education, calculated to develop and strengthen his mental powers as well as to store his mind with knowledge.

2. Since the circumstances of parents differ, gradation of schools is necessary; and, looking specially to those required for children who are intended for industrial pursuits, we think that they should be organized with a view to the education of children up to their *thirteenth* and their *sixteenth* year respectively, the former class being called ELEMENTARY, and the latter class SECONDARY.

3. In connection with both we believe that school-workshops should be established.

4. If schools took upon themselves the training of their pupils in the elementary parts of workmanship, apprenticeships might be reduced as to duration, the reduction being at least *two years* in the case of pupils of secondary schools

5. Trades should be taught systematically for some time to young people after they leave school—the place in which this teaching is given being either in a special building detached from an actual workshop, or within such workshop, according as experience may suggest.

Referring for a moment to the labours of the two Royal Commissions at present engaged with educational questions, we quite expect that very valuable light will be thrown upon the teaching of trades by the Commission on Technical Education. So far as the steps that have yet been taken by the members of that Commission are known to us, we are disposed to expect from them a very careful and extensive collection of facts, together with a judicious discussion of the lessons that are to be drawn from these facts for the guidance of those interested in the education of the industrial population of this country. As to the labours of the Commissioners on Educational Endowments, it is, of course, premature to do more than state our general desire to see something considerable done in the way of secondary education. We may add that the kind of secondary school that should receive most attention is, in our opinion, the one we have advocated for the education of boys intended for industrial pursuits. We think that schools which receive pupils for the learning of a trade are also suitable objects for the consideration of the Commissioners. Finally, we think it would be quite in the line of their duties to make, as far as circumstances will permit, provision in the form of bursaries tenable at secondary or technical schools for the better education of really clever boys belonging to the working-classes.

III.—*On the Decay of Building Stones.* By WILLIAM WALLACE, Ph.D., F.R.S.E., F.I.C., F.C.S.

[Read before the Architectural Section, 29th January, 1883.]

THE comparative durability of the varieties of stone suitable for building purposes is a theme of great interest to the architect; and this must plead my excuse, as a chemist, for intruding myself upon the members of a Society wholly engaged with matters connected with architecture and building construction. The most casual observation shows the most striking differences in the rocks which are brought to view by the operations of nature—some remaining firm and hard after countless ages of exposure to wind and rain, while others, under similar influences, have crumbled into dust. And again, an examination of the works of the architects and workmen of the old world exhibit differences not less striking. Many of the monuments of ancient Egypt and Greece show, even now, only the slightest traces of decay; while in our own country most of our cathedrals, and old churches, castles, and baronial halls have suffered great deterioration, and many of them are only saved from complete destruction by a careful system of renovation. No doubt it is scarcely fair to compare the durability of buildings in countries where rain seldom falls with those exposed to our own humid climate; but apart from this we have instances in our immediate neighbourhood which show the variations in regard to durability in different building materials exposed to the same climatic influences. While the old ecclesiastic buildings and baronial mansions, only a few centuries old, and constructed for the most part of red sandstone, are mostly in ruins, with the stone ridged and furrowed, and the mouldings and carving all but obliterated, we find in the Roman Wall, stretching from the Forth to the Clyde, as seen near Kirkintilloch, blocks of whinstone from the neighbouring quarry of Auchinsterry, in which we can almost see the marks of the workmen's tools, and which are really,

so far as we can see, as fit for use now as the stones just taken from the quarry. Again, in some old feudal castles, built partly of mica schist, we find pieces of that excellent, but most intractable, building material with angles as sharp as if they had just been removed from the rock.

The principal building stones employed in this country for city architecture, if we except granite, the use of which is confined to one particular town and district, and which does not lend itself kindly to the artistic aspirations of the architect, are—1. Sandstone, or as it is generally called by builders, on account of the ease with which it is wrought, freestone; 2. limestone in its more compact form; 3. oolitic limestone; and 4. magnesian limestone or dolomite. In the present short paper I propose to deal only with the first of these—sandstone—as it is the only one with which we are locally interested, all our buildings being constructed of that material, which occurs in great abundance in the new red sandstone, the carboniferous, and the old red sandstone strata. It is a common matter of observation that, apparently, little care is taken in the selection of the stone, even in cases where durability is most important; and it is a fair inference that architects really do not know now to distinguish a stone that will stand well from one that will rapidly decay. Certain quarries acquire a reputation because experience has shown that the stone taken from them has stood well; but the architect or builder who selects it, cannot tell in what respect it differs from another stone that is known to be bad. It is in the hope of being able to throw a little light on the subject that I have ventured to introduce it, trusting that my remarks will lead to a discussion that will bring out many points of interest.

I have to acknowledge my indebtedness to Messrs. Watt & Wilson, Contractors, for kindly supplying me with twelve specimens of stone from well-known quarries. Of these I have made careful chemical analyses, and the results are contained in the table I have suspended on the wall, and to which I shall frequently have occasion to refer. In regard to one of them, the first on the list, from Kenmure, Bishopbriggs, Messrs. Watt & Wilson say in their letter accompanying the specimens—"This seems to be a picked bit: it is well known that there is not much good weather stone to be got in the Bishopbriggs quarries now." In a letter of more recent date, in answer to an inquiry, they say it is from a new quarry, and that the quantity obtainable is probably not large.

Let us see, in the first place, what sandstone is. Its chemical composition, as well as its physical character, shows it to consist essentially of particles of sand—in other words, crystallized or crystalline silica—formed, no doubt, by the disintegration of older rocks, and washed by the action of water into beds, sometimes of great thickness, where, by the infiltration of other substances, such as lime in solution, it has gradually been consolidated until it became a firm rock. Among the mineral substances found in sandstone, in addition to the leading ingredient, silica—the most important, undoubtedly, as regards the formation of a hard and durable rock—are the carbonates of lime and magnesia. So great is the effect of these bodies in filling up the intervening spaces between the particles of sand and forming a firm mass, that the durability of a stone may, with tolerable accuracy, be deduced from the proportion of these compounds found in it. In the twelve specimens I have examined in connection with this paper, the amount of these carbonates varies from ·57 to 12·58 per cent. I have to direct your attention, however, to the Craigleith stone, which is well known to be one of the most durable of its class, but which contains the smallest quantity of carbonates—·57 per cent. Now, this stone is one of the heaviest in the list, and it is the least porous of all; whereas in the others the weight is directly, and the porosity inversely, proportionate to the quantity of the carbonates of the alkaline earths. The fact is that this Craigleith stone is not a true freestone or sandstone, but approaches in its nature to the "kingle" of mining engineers—a kind of quartz rock, or metamorphosed sandstone of great hardness. How it is formed is probably not certainly known, but my impression is that it has become indurated by an infiltration of silica dissolved in water which has percolated through it. I understand that this stone, which is very hard, is chiefly used for the steps and landings of stairs, and very little, if at all, for general building purposes.

The alumina, the proportion of which varies from ·32 in the yellow Polmaise stone to 1·77 in the pink-coloured Inverkip stone, is probably due to the undecomposed minerals associated with the sand, and is not likely to have much influence on the strength or durability of the stone. When, however, it exists in the form of clay, as is sometimes the case (and probably clay exists to a small extent in all sandstones), it is adverse to the durability of the stone.

The oxide of iron is interesting as forming the colouring matter

of the red varieties of sandstone; but it exists in all to a greater or less extent. It appears somewhat anomalous, but it is the fact, that some of the whitest specimens contain more oxide of iron than those of a bright red colour. Thus the Kenmure and Overwood stones gave, on analysis, respectively, 2.62 and 2.5 per cent. of oxide of iron; while the Bothwell Park and Wemyss Bay samples gave only ·98 and 1·05 per cent., or less than half the quantity. The colour of a stone, therefore, does not give the slightest clue to the amount of oxide of iron it contains. The smallest proportion in any of the specimens is in the Ravenscraig stone, which remains perfectly white when calcined, while all the rest become more or less coloured when ignited. My idea is that in the red stones, such as Corsehill and Wemyss Bay, the oxide of iron exists in the free or uncombined state—that is, mechanically mixed with the other constituents; while in the white varieties it is in combination, probably as a silicate of the protoxide. In yellow stone, such as the Polmaise, it probably exists in the free state, but in a hydrated condition, as these stones become bright red when subjected to a strong heat. It is well known to builders that some kinds of sandstones are liable to become disfigured with blotches, or spots of oxide of iron. This arises from patches, or nodules of pyrites, in the stones, which are readily altered by exposure to air and water, forming sulphate of iron, which gives yellow hydrated peroxide on coming to the surface; the sulphuric acid being taken up, wholly or in part, by the lime and magnesia present in the stone.

The remaining mineral constituents of sandstones—phosphate and sulphate of lime—exist in quantities too minute to exercise an appreciable influence in their hardness, strength, or durability. They are interesting rather from a scientific than a practical point of view.

The quantity of water retained after long exposure to the air in a moderately dry atmosphere is very small, and varies from a mere trace up to about 2 per cent. There is no reason to doubt that it is influenced by the temperature and degree of humidity of the air.

We have now two physical properties of sandstones to consider; their weight or specific gravity, and their porosity, as indicated by the quantity of water they absorb when immersed in that liquid.

The table shows the specific gravity, and, calculated from that,

the weight of a cubic foot in pounds, and the number of cubit feet in a ton. In all cases the stone was air-dried. The lighest stones were the Ravenscraig, Bothwell Park, Corsehill, and Wemyss Bay, and the heaviest were the Kenmure, Overwood, Craigleith, and Polmaise—the heaviest of all being the Kenmure, with its 9 per cent. of carbonates of lime and magnesia. The latter weighs 144 lbs. per cubic foot, while the Bothwell Park weighs only 127½ lbs., a difference which is very striking.

The quantity of water the stones are capable of absorbing appears to be closely connected with the specific gravity. The best stone in this respect is the Craigleith, which takes up only 3·4 per cent.; the Kenmure comes next, with 3·9 per cent.; the Polmaise faintly pink or white stone, which is very high in lime and magnesian carbonates, is nearly as good, with 4·4 per cent. The Overwood and Dunmore stones take 5 and 5·1 per cent., and the Giffnock and Ravenscraig 5·9 and 6·1 per cent. respectively. The Polmaise yellow stone takes 5, and the Inverkip slightly pink stone 5·5 per cent. The greatest quantity is absorbed by the red stones, which take up respectively 6·1, 6·4, and 7·2 per cent.—the last proportion being that taken by the Wemyss Bay stone.

I am not inclined to dogmatize in the matter of the interpretation of these results, but I think you will have no difficulty in agreeing with me that, as a general rule, a sandstone is the better the heavier it is, the less water it absorbs, and the more its pores are filled up with cementing material, such as the carbonates of lime and magnesia. Taking all these considerations together, I would prefer for building purposes, of the twelve stones contained in the table, the Polmaise light coloured stone and that from Kenmure, both of which I would regard as of first-class quality. Again, among the other white stones, I would not hesitate to prefer the Overwood and Dunmore stones to that from Ravenscraig. The three dark red stones I would consider inferior in quality for outside work, especially in the atmosphere of a city, which is something distinctly different from the air of the open country.

The usual form of decay of sandstones is simply the disintegration of the surface, the binding material being removed by climatic influences, and nothing left but the sand, which may be rubbed off freely with the hand. There is, however, another form of disintegration which I had a few years ago occasion to investigate—that in which the surface comes away in distinct scales. The

building was a ducal mansion of large dimensions, and a sandstone was used which contained an unusually large proportion of alumina, with a very fair quantity of carbonate of lime. After a year or two the surface began to scale off, particularly at angles, curves, and other exposed parts, especially close to the ground; and the scales were about $\frac{1}{8}$th of an inch thick and very uniform. I found that the original stone contained 5·2 per cent. of carbonate of lime, while in the scales it was reduced to 2·04 per cent. I had no doubt at the time, nor have I any doubt now, that the reduction of this ingredient was closely connected with the disintegration, if not its actual cause.

Sandstone is very porous, and absorbs water with avidity. A moderate shower of rain falling on the surface of a building constructed of freestone is entirely absorbed, at least at first, until the surface becomes saturated with water. The carbonates of lime and magnesia are only very slightly soluble in pure water, but much more so in water containing carbonic acid, as all waters do to a greater or less extent, although the proportion in rain water is very small. Every shower that falls, therefore, removes a certain very minute quantity of these binding materials, and in a correspondingly minute degree weakens the stone. But this same operation, constantly repeated year after year, begins by-and-bye to tell upon the stability of the surface, and particularly if the stone have only a minute quantity of the earthy carbonates to start with. In towns we have also sulphuric acid in the air in appreciable quantity, and the rain that falls first is generally acid to litmus paper. This is derived from the sulphur in coal and from various manufacturing operations; and, of course, is more abundant in large and closely-built towns than in those which are small and widely spread out. It follows that a stone which stands well enough in the country, or in a small town or village, may be very unsuitable for a large city; and the same thing applies to roofing slates, some of which are much more affected by acids than others.

If the walls of houses were entirely vertical, without any horizontal surface to catch the rain, the deterioration of stone would go on with extreme tardiness; but, as a matter of fact, there is a great deal of horizontal work about our houses and other buildings, consisting of window sills and lintels, porches, capitals, string courses, plinths, and so on—all these forming receptacles for catching the rain, a large proportion of which percolates through the stone and appears at a lower level. If you examine a few of

the more recently erected buildings in Glasgow, where disintegration of the stone has set in, you will find that the process always shows itself first immediately below a flat projecting surface; and frequently there is no apparent injury to the stone elsewhere. The flow of rain water over the surface of stone injures it only very slowly; the greater part of the damage is done by water passing through the stone, entering on a flat, or nearly flat, surface and passing out at a lower level. In this way the stone in ordinary weather, alternately fair and rainy, never gets time to dry, but is always more or less damp.

The form of architecture adopted by the Greeks, and which in its pure or modified form is much used in city architecture, is well suited for a dry and warm climate, but much less so for a humid condition of atmosphere, such as that which obtains in this country. The Gothic style of architecture, whether accidentally or intentionally I cannot say, is better adapted to our climate; since the projecting courses of masonry are for the most part in the form of pointed arches, which permit the water to run rapidly off. Not that I would for one moment suggest that we should discard the Greek and Italian styles and adopt the Gothic; but I think something might be done to render these styles compatible with the exigencies of our over-humid climate. This brings me to what is, perhaps, the most important part of my communication—*i.e.*, the suggestion of means by which the decay of sandstone may be prevented or retarded.

Of course, the first consideration is to select for a building—and especially if it be one of a public and important character—a stone of the first quality. Next in order of importance is the covering of all flat, or nearly flat, surfaces with something that will prevent the rain which falls from passing through the stone. But I would advise architects, as far as possible, to avoid flat surfaces, and to give to window sills and all projections as steep a slope as is consistent with the character of the building. A plan which I have advocated, and which is particularly adapted to projecting work at a considerable elevation, is to fill in the angle with Portland cement, so as to make a rather steep slope, which will completely prevent water from lodging or passing through the porous stone. This has also the merit of securely covering the joint between the projecting course of masonry and the flat stone immediately above it. When the use of cement is objectionable, the slightly-sloped surface should be coated twice or three times with a tolerably

strong solution of water-glass or silicate of soda, which will effectually fill up the pores and prevent water from passing through the stone. White-lead paint mixed with boiled oil may also be used but it must not be applied to the stone until it is perfectly dry, and three or four coats are required. If all the projecting surfaces are thoroughly protected in any of these ways, the covering of the perpendicular surfaces is of comparatively little consequence, and will not be required unless the stone is of very bad quality. In extreme cases it is necessary to coat the whole surface with oil paint or silicate of soda—both of which, however, are inapplicable to a grand public building, the painting of which would be justly considered as an act of Vandalism as great as the plastering up of the grand old Gothic columns in some of the English cathedrals, which was practised in an age more remarkable for sturdy piety than for cultivated taste and artistic skill. There is a material, however, which I may mention to you, which gives a complete and impervious coating to polished ashlar without materially changing its colour or general appearance. It is prepared by the Broxburn Oil Coy., and is called "Alexinoton, or damp repeller." I am not at liberty to state the composition of the liquid, but may merely say that it is a solution of a solid body in a highly volatile liquid. When applied to a wall the volatile solvent speedily evaporates, and the deposited solid completely fills up the pores on the surface, and renders the stone impermeable by water. This liquid may be applied not only to flat, or nearly flat, surfaces, but to an entire building; and I consider it particularly valuable for coating elaborate work, such as the capitals of pillars.

Where an entire building is coated with an impervious substance —which, in the case of ashlar, may be any of the liquid applications I have mentioned, and in rubble work or brick may be Portland cement or mastic—it is of the utmost importance that the walls should be allowed to dry first. A two-foot wall will take, at the very least, two years to dry, and the quantity of water that passes away from it is larger than might be supposed. A fair-sized country villa, say 50 feet square and 30 feet high, will contain about 8,000 cubic feet of solid masonry, weighing about 500 tons, which will contain, as originally built, about 25 tons of water or 5,600 gallons—and all this has to be evaporated before the house is comfortable or safe to live in. Probably it makes its escape about equally from the outside and the interior; but, at all events, the process is a slow one, and in the case of buildings not protected

by a damp course from water sucked up by the porous stone from the foundations, it is never complete. It is, therefore, unwise to coat the walls of a house with an impervious coating until towards the close of the second summer after the completion of the house. This rule does not apply, however, to coating the flat and other projecting surfaces, which may be carried out at any time during dry weather.

I now leave the subject in your hands, in the hope that the discussion will be more important than the paper itself.

ANALYSES OF TWELVE SAMPLES OF SANDSTONE OBTAINED FROM MESSRS. WATT & WILSON, CONTRACTORS.

AIR-DRIED.

Name of Quarry,	Kenmure.	Overwood.	Giffnock.	Dunmore.	Ravenscraig.	Craigleith.	Polmaise.	Polmaise.	Inverkip.	Bo'well Park.	Corsehill.	Wem'ss Bay.
Colour of Stone,	White.	White.	White.	White.	White.	White.	White.	Yellow.	Light pink.	Red brown.	Red.	Red.
Silicious Matter, insoluble in acid,	86·26	88·86	94·94	94·48	96·99	98·29	84·14	93·20	95·76	95·28	94·32	96·67
Alumina,	·80	1·19	·56	·68	78	·49	·52	·32	1·77	·51	1·34	·81
Peroxide of Iron,	2·62	2·50	1·22	·80	·14	·27	1·92	1·20	·47	·98	1·70	1·05
Carbonate of Lime,	5·72	2·30	1·28	2·47	·31	·36	7·92	2·94	·30	·51	·44	·37
Carbonate of Magnesia,	3·33	1·97	·89	1·13	·21	·21	4·66	1·57	1·16	·33	·59	·74
Phosphate of Lime,	·15	·11	·07	·04	trace	·04	·08	·03	·05	·04	·11	·09
Sulphate of Lime,	·09	·10	·06	·07	·05	·08	trace	·03	·08	·07	·05	·08
Loss on Ignition,	·75	·62	1·10	·35	1·17	·28	·04	·55	·24	...	·33	·26
Water at 212° F.,	·11	2·10	·04	·20	·18	·09	·04	·09	·32	1·42	·72	·30
	99·83	99·75	100·16	100·22	99·83	100·11	99·32	99·93	100·15	99·14	99·60	100·37
Specific Gravity,	2·318	2·249	2·113	2·165	2·052	2·260	2·192	2·202	2·137	2·048	2·063	2·078
Weight of a Cubic Foot, lbs.,	144·4	140·1	131·7	134·9	127·9	140·8	136·6	137·2	133·2	127·6	128·6	129·5
Cubic Feet per ton,	15·5	16	17	16·6	17·5	15·9	16·4	16·3	16·8	17·5	17·4	17·3
Absorption of Water, per cent..	3·9	5·0	5·9	5·1	6·1	3·4	4·4	5·0	5·5	6·4	6·1	7·2
Colour after Ignition,	Dark reddish grey.	Reddish grey.	Grey.	Light grey.	White.	Nearly white.	Yellow grey.	Red.	Light red.	Rather dark red.	Deep red.	Deep red.
Total Carbonates,	9·05	4·27	2·17	3·60	·52	·57	12·58	4·51	1·46	·84	1·03	1·11

IV.—*On some new Infusoria.* By WILLIAM MILNE, M.A., B.Sc.

[Read to the Society, 31st January, 1883.]

THE following four organisms were got in gatherings made from a large ditch, now stagnant, and filling up with moss and weeds. The ditch is near the sea and subject to the spray in storms; the water is thus brackish, giving a heavy precipitate with silver nitrate. The first three organisms appear and flourish for months in small bottles among the decaying organic matter. They are found in company with Tetramitus descissus and Chilomonas paramecium.

Tetramitus gyrans.—This is a free swimming form. The body substance is very transparent, soft, but not changeable in shape. It presents three different views, dorsal and ventral the same, nearly circular; lateral views the same, the anterior half being bulb-shaped, slightly compressed, the posterior half being a narrow stem. The apical view is a little sigmoidal, the form differing somewhat as it is more or less canted over. The anterior half of the organism is thus a partly flattened bulb, the stem of which is continued to the posterior end. This part appears denser, containing numerous foreign particles, and cuts off two lateral laminate segments in the after half. At the points where these laminate portions terminate, fully half-way forward, are inserted the four flagella, two on each side equal, about twice the length of the body, and very fine and flexible throughout. There are two contractile vesicles in the longitudinal axis, both posteriorly situated. Length, $\frac{1}{110}$ inch to $\frac{1}{150}$ inch.

This form differs slightly from the generic description of Tetramitus as regards insertion of flagella. There is the possibility that it is the young condition of Trepomonas agilis, which has four flagella according to Stein. It is here considered not to be the same, as the shapes seem to be quite distinct, but as this view might be formed owing to a misinterpretation of Stein's figures,

great care has been taken in searching for an example among T. gyrans with two flagella. This has not been found after dozens of trials through an interval of more than a month, nor has a single instance of the adult Trepomonas agilis been seen along with T. gyrans, and often there were hundreds of the latter under the cover glass at one time. Also specimens of T. agilis were examined, but none were seen to give the same views as T. gyrans, not even an example with four flagella which was about to divide.

A specimen of the present species was observed with what looked like a long bacterium adhering to it, or fission commencing; but on being watched, this bacterium-like extension lengthened, and by it the animalcule attached itself to the slide and swung round in circles. Two instances only of this attachment were seen. In both cases the extension was broken off and left behind. It is exceedingly active, constantly turning on its longitudinal axis, even though remaining in one place for a considerable time. Its forward motion in a straight course is also by this turning on its axis, giving a regular motion. The flagella are lashed out in the most graceful curves, and the spin is made from the broad surface, a half turn at a time, the lateral view just seen darker in the passing. The two transparent membrane-like segments in this way look with low powers, as if they were contracting or collapsing, each contraction giving a forward impetus. When changing its direction it generally drops from the horizontal to the perpendicular, showing the apical view (Fig. 3). This continual spinning causes an inflow of food particles, some of which get thrown on to the body.

Hexamita Kentii.—This form is mostly adherent, but also free swimming. It is very irregular but persistent in shape. The usual dorsal view is triangular, the two lower corners as if they were ear-like processes moulded on; the lateral view is oval with one of the processes seen (Fig. 5), and when seen from either end it is somewhat like a cross (Fig. 6). To the two processes mentioned above are fixed the six flagella—three to each. There are two trailing ones from three to three and a-half times the length of the body, by which the animalcule moors itself, and two vibratile ones on either side about the length of the body. The body is transparent, and is seen to contain several food particles, which keep up an irregular circulation. There is one contractile vesicle half-way between the lower corners. Length from $\frac{1}{150}$ inch to $\frac{1}{500}$ inch.

The usual condition of this Hexamita is the adherent, and where the algæ and moss collect on the slide there may be seen at the out edges several examples swinging round at the full stretch of their long flagella. All the different views may then be seen, but generally the triangular one. This again is the view if the hold gives way and the animalcule dashes off at no great rate, till the flagella—which are kept twisted at the ends—catch hold of some other substance and bring it up, unless they have caught some minute particle, which is dragged along until something heavier is held, when the little animal resumes its fishing. This it does by means of its vibratile flagella lashing about, causing currents which bring along particles. When the flagella feel any of these, they lash round in the direction of the depression, where the ear-like part joins the body. If the particle has been successfully thrown into this hollow, it quickly penetrates into the body and courses swiftly round by the apex of the triangle. Several of these particles may be seen in the body at one time circulating irregularly. This opening looks very like an oral aperture, and all the particles which were seen to be incepted were taken in here—in one instance, two in less than five minutes. But, of course, these instances may have been luckily happened on. Of the four short flagella, two, one on either side, are rather shorter and more vibratile than the other two. H. Kentii is more adherent than H. inflata, and when free is not so quick in its motions, nor has it been observed to take creeping protean forms like the latter. I have ventured to name this flagellate after Mr. Saville Kent, the distinguished authority on this subject.

Longicilium flexicuneus.—This is a free swimming cilio-flagellate animalcule, persistent in shape. The shape is that of a strained wedge, the tranverse section being triangular—the triangles lessening very quickly towards the two ends. There is a slight ventral groove, and through this the oral aperture enters. The aperture also extends on one side to the lower lateral edge. It is situated a short distance from the anterior end, the groove in front forming a sort of leading way to it. Three-fourths part of the body from the anterior end is covered sparsely with long vibratile cilia. The flagellum is about half the length of the body and is situated posteriorly. There are longitudinal striæ in the anterior half, and green granular particles in the endoplasm. The contractile vesicle is conspicuous about one-third forward. Length, $\frac{1}{450}$ inch to $\frac{1}{600}$ inch.

The shape of this organism is peculiar. Imagine a wedge-shaped piece of semiplastic material whose length along the back is one-and-half times the depth, and the thickness of the back about half the depth. The two triangular ends are brought to minute triangles by slicing along the sides, but to no great distance from the ends. If the ends be held, and a twist given with each hand, a form would be got something like that of this cilio-flagellate.

The cilia round the oral aperture and forward are more thickly planted, and work more vigorously than further back. All the cilia are very long and very flexible, working after the manner of a short cord when held by one end, and moved backwards and forwards.

Occasionally there may be seen a transparent part at the after end, from which all the granular matter has been withdrawn. In one or two such instances, at the edge of the transparency, a round part filled with granules whirling about among each other, was seen, which soon burst, and the granules spread over the transparent section. Fully half the body was sometimes seen to be honey-combed—the granules being gathered up into the boundaries.

It is very voracious, crushing in amongst and browsing on the vegetable *debris*. At these times the flagellum can be well seen in motion. When not feeding it swims very fast, turning on its axis, and tracing a winding curve round its course.

This form is put forward as the representative of a new genus, as it differs from the generic description of Trichonema, in shape, in being persistent in shape, in the position of the flagellum, and the length of cilia.

It also differs from Mitophora the only other near genus, in shape, in not having a fringe only of cilia, and in having a very distinct oral aperture.

Tillina barbata.—The body is bean-shaped, about twice as long as broad, and is compressed on the side opposite the oral aperture. The oral aperture is about one-fourth way from the anterior end, lateral, and forms a broad cleft well into the body, leading into a pharynx which is slightly curved at the end, and ciliated throughout. The whole body is covered with very fine cilia, there being also a beautiful adoral frill of longer cilia. The cuticular surface is very elastic, and regularly striate longitudinally. The contractile vesicle is posteriorly situated, and the nucleus, which is elongate, is well forward. Length about $\frac{1}{175}$ inch.

T. barbata differs from T. magna in having no lobate process developed on it, in the position of the oral aperture and the pharynx.

The individuals of this species were not very numerous, and disappeared in a fortnight after the first one was noticed.

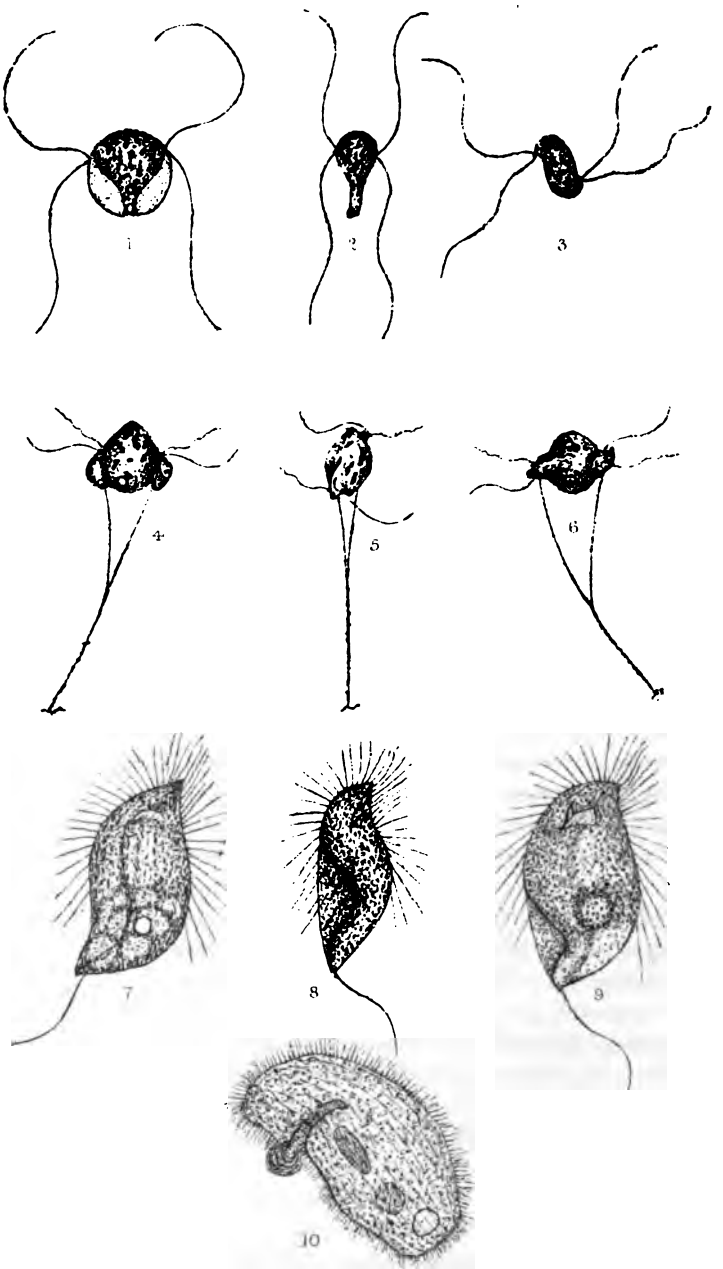
EXPLANATION OF PLATE.

Fig. 1—3.—*Tetramitus gyrans*, × 600.
1. Dorsal view. 2. Lateral view. 3. Apical view.

,, 4—6.—*Hexamita Kentii*, × 600.
1. Dorsal view. 2. Lateral view. 3. Apical view.

,, 7—9.—*Longicilium flexicuneus*, × 500.
1. Dorsal view. 2. Lateral view. 3. View between Lateral and Dorsal.

,, 10.—*Tillina barbata*, × 200.



Maclure & Macdonald, Lith.rs Glasgow

V.—*Note on a Simple Form of Lippmann's Capillary Electrometer useful to Physiologists.* By JOHN G. M'KENDRICK, M.D.

[Read before the Society, 17th January, 1883.]

THE action of the substances set free on the electrodes in electrolytic decomposition, and the energy shown as motion in these circumstances, is strikingly manifested by the behaviour of a drop of mercury in dilute sulphuric acid, when the positive pole of a battery is put in connection with the mercury, and the negative pole dips into the acid. The mercury extends towards the negative electrode during the passage of the current, becoming covered with a film of sub-oxide, which dissolves in the acid, leaving a bright surface. By making and breaking the current a series of oscillations is set up. Movements in the mercurial electrode and adjacent acid have been observed by Henry, Gerboin, Erman, J. F. W. Herschel, Draper, Paalzow, Faraday, and Quincke,* and they received various explanations. Erman,† in 1809, was the first to observe that when a drop of mercury was placed on a grooved surface between the electrodes it moved towards the negative pole; and he also observed that "a drop of mercury in a horizontal tube, with dilute acid on both sides, moved at the passage of the electric current through the tube towards the negative electrode."‡

This latter phenomenon was fully investigated by Lippmann,§ and led, along with researches by Quincke, not only to a theoretical

* For an historical account of this subject see Lippmann, *Annales de Chimie et de Physique*, 1875, p. 540. Also references in arts. "Capillary Action," by Professor Clerk Maxwell, *Encyclop. Britann.*, vol. v., p. 65; and "Electrolysis," by Mr. W. N. Shaw, vol. viii., p. 108. See also art. "Electricity," Watts' *Dict. of Chem.*, third suppl., vol. viii., part i., p. 714.

† Gilbert's "Annalen," t. xxxii., p. 261, 1809.

‡ Art. Electrolysis, *op. cit.*

§ Lippmann, *Comptes Rendus*, 1873, p. 1407; *Annales de Chimie et de Physique*, 1875, p. 494; Poggendorff's *Annalen*, cxlix., p. 547; also translated in *Phil. Mag.* [4], xlvii., p. 281.

explanation of electro-capillary action, but also to the construction of the capillary electrometer. It is now known that these phenomena, both as seen in the experiment with the globule of mercury and in the capillary tube, are due to a change in the surface tension produced by the electrical polarization of the surface of the mercury.

Lippmann's form of the electrometer consists of a tube of ordinary glass, 1 metre long and 7 millimetres in diameter, open at both ends, and kept in the vertical position by a stout support. The lower end is drawn into a capillary point, until the diameter of the capillary is ·005 of a millimetre. The tube is filled with mercury, and the capillary point is immersed in dilute sulphuric acid (1 to 6 of water in volume), and in the bottom of the vessel containing the acid there is a little more mercury. A platinum wire is put into connection with the mercury in each tube, and, finally, arrangements are made by which the capillary point can be seen with a microscope magnifying 250 diameters. Such an instrument is very sensitive; and Lippmann states that it is possible to determine a difference of potential so small as that of the $\frac{1}{10.080}$ of a Daniell. It is thus a very delicate means of observing and (as it can be graduated by a compensation-method) of measuring minute electro-motive forces.

As the sensitiveness of the instrument depends essentially on the smallness of the capillary tubes, and on the constant electromotive force between the mercury and the sulphuric acid (termed by Lippmann the *différence électrique*), it is important to have the tube as fine as possible, and also to prevent variations in the strength of the sulphuric acid by evaporation. These considerations led to improvements in the construction of the instrument, thus described by Burdon Sanderson:*—"Two important improvements have been recently made in the construction of this instrument by Professor Lovén,† of Stockholm. The first of these consists in

* Burdon Sanderson "On the Electro-motive Properties of the Leaf of Dionæa in the Excited and Unexcited States."—*Phil. Trans.*, part i., 1882. See also his lecture "On the Excitability of Plants," at the Royal Institution of Great Britain, 9th June, 1882. In stating his opinion that "it is much better to measure the electro-motive value of each excursion with the aid of the compensator, than to deduce it, as has been done by Fleischl, from the 'compensation pressure,'" Dr. Burdon Sanderson refers to Fleischl's paper, *Archiv. f. Anat. v. Physiol.*, 1879, p. 269.

† Lovén. *Nordiskt Medic. Arkiv.*, vol. xi., No. 14.

constructing the tube which contains the dilute sulphuric acid of extremely thin glass, so that the capillary tube which is in contact with its internal surface can be observed with a magnifying power of at least 300 to 400 diameters (No. 10 Hartnack). The other consists in cementing the sulphuric acid tube to the mercury tube, so that no evaporation takes place. By the first the instrument is rendered much more sensitive; by the second, variations in the strength of the sulphuric acid which arise from evaporation are avoided."

The instrument thus described is difficult to make, and requires delicate handling. Whilst studying the subject, and endeavouring to see the phænomena for myself, I resorted to the simple expedient of taking a bit of glass tubing, 60 millimetres in length, and 2·5 millimetres in internal diameter, bending one end at a right angle, 20 millimetres from the end, and the other end at a right angle, 6 millimetres from the end, and then drawing out the tube to a capillary in the blow-pipe flame. The diameter of the capillary tube varies from ·02 mm. to ·001 mm. I then slip a bit of thick-walled india-rubber tube on one end of the glass tube, and exhaust the other end of the india-rubber tube with a powerful syringe. Having some clean mercury in a beaker covered with a deep layer of dilute sulphuric acid (1 to 20 of water by volume), I first immerse the end of the glass tube into the mercury, and then exhaust by the syringe. When mercury appears in the upper portion of the tube, I raise it a little so as to cause it to dip for an instant into the dilute acid, and then I dip into the mercury a second time and draw a little more of it into the tube. Thus, with a little practice, I succeeded in filling tubes, so that there is a reservoir of mercury at each end, with a little sulphuric acid in the centre of the capillary. This is placed on a suitable platform on the stage of the microscope, and a thin platinum wire is dipped into the mercury at each end.

Such an instrument is very sensitive, showing the muscle-current, the negative variation, and the changes in potential in the injured heart of the frog whilst beating. As observed by Burdon Sanderson, it is striking to notice "that the movements of the mercurial column not only correspond closely in time to the actual changes which they represent, but express with very great accuracy the differences of potential which actually exist in each successive phase of a variation."

It will be found that, in the instrument I have described, the

column of mercury will not always return to zero when the electro-motive force pushing it in one direction has ceased to act. When it does return, the return is due to the pressure of the column of mercury against which the force acted. As a matter of fact, the most sensitive instruments are those which do not return to zero, but in which the movement of the mercurial column corresponds to each change in the direction of the electro-motive force, or to any increase or diminution of the electro-motive force even in one direction. Thus, if there be a negative oscillation, it will be at once seen, although it last for a fraction of a second. Sometimes the instrument is "sluggish" in its movements. This is caused by the mercury, or the acid, or the tube not being perfectly clean.

An electrometer such as this can have its deflections photographed* or exhibited on a screen, whilst its simplicity and cheapness makes it possible to place a sensitive instrument in the hands of every student—or, better still, a student may make it for himself. †

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* Marey obtained such a photograph in his research on the Electrical Discharge of the Torpedo (*Physiologie Expérimentale*, 1877, p. 33, Fig. 19), and Burdon Sanderson has photographed the oscillations caused by the changes of potential in Dionæa, and in the frog's heart.—Royal Institution Lecture, Fig. 10.

† Various forms of the instrument were shown, and the oscillations of the mercury were projected on a screen, the oscillations being magnified 300 diameters. There is nothing novel either in the theory or in the mechanism of this instrument, as it in no way differs, except in simplicity of construction, from one exhibited at the meeting of the British Association in Glasgow in 1876, by Professor Dewar of Cambridge, but I have shown an easy and convenient mode of making an instrument of exquisite delicacy for physiological purposes. A drawing of Prof. Dewar's form of the instrument is shown in Dr. S. P. Thompson's recent work on Electricity.

VI.—*On Milk and Milk Pollution.* By JOHN DOUGALL, M.D.

[Read before the Society, 15th November, 1882.]

IN the spring of 1873 I read a paper* before the Sanitary Section of this Society, "On the Dissemination of Zymotic Diseases by Milk." At that period strong suspicion was culminating in fact, that milk was a vehicle of specific infection, either by its having been exposed to an infected atmosphere, or directly impregnated with impure water, or otherwise, so that persons drinking such milk were liable to be poisoned thereby. Previous to that time, Dr. Taylor, Penrith, had written upon disease caused by ingesta; Dr. Ballard, London, had reported an epidemic of typhoid at Islington produced by adding impure water to milk. In Leeds, two similar epidemics and one of scarlatina were reported by Dr. Robinson, apparently from the same cause. Professor Bell, of St. Andrew's, now deceased, published an account, and afterwards sent me additional particulars of an epidemic of scarlatina from poisoned milk. My friend, Dr. Grimshaw, of Dublin, now Registrar-General for Ireland, favoured me with a narration of cases of Asiatic cholera and of small-pox, suspected of having been caused by milk, and, just at that time, Dr. Russell had submitted to the Police Board his very able report of an epidemic of typhoid at Parkhead, which, I think, he clearly and conclusively traced to milk contaminated by exposure in an atmosphere polluted by typhoid excretions.

At that time also, as was to be expected, a considerable number of medical men were sceptical about the new doctrine of milk-poisoning, and I remember, on the day after reading my paper, of a well-known Glasgow practitioner, a strict Conservative in medicine, calling upon me, in a state of incandescence, about "this preposterous milk-poisoning theory," as he termed it, and seriously offering to prove its absurdity by swallowing milk to which a portion of typhoid excreta had been added! Of course for many obvious reasons the experiment was not made.

* Vide *Glas. Med. Jour.*, May, 1873.

It was in consequence of the great divergence of opinion then prevailing in regard to milk-poisoning that I set about collating facts regarding it, and of examining the chemical constitution of milk, with special reference as to whether it was a favourable *nidus* for the reception and dissemination of zymotic poison. The facts and considerations referred to were embodied in my paper, and clearly showed that sweet milk is a congenial soil for the preservation, and probably even the multiplication of specific infections.

It is almost superfluous to remark that, since that time (nine years ago), the views then enunciated have had many sad witnesses to their truth in the shape of a very considerable number of extensive epidemics, chiefly of typhoid, throughout Britain. These, after being carefully sifted and winnowed for their causes, by men eminently qualified for the work, the conclusions arrived at were, as the means taken for their arrestment proved, that their epidemic form was due to the distribution and swallowing of poisoned milk.

The serious character and frequency of these outbreaks latterly impressed Local Authorities with the necessity of legislating for the control of their milk supplies; hence in Glasgow—and, if I am rightly informed, in several other towns in Britain—the retailers of milk are now placed under certain restrictions in order to prevent, as far as possible, contamination of milk to any degree. In giving these restrictions legal effect, a point of primary importance is this, viz.:—What are the conditions under which milk may become accidentally polluted? because there are practically no reliable chemical or microscopical tests by which ordinary accidental impurities can be detected in milk, and yet it may not only be simply impure, but fatally poisonous. It was to determine this point with special reference to the prosecution of an alleged defaulting milk retailer, that I made certain experiments as to the tendency of milk to absorb various volatile bodies, which, although they might not in ordinary circumstances render it poisonous, would at least make it impure.

Before proceeding to detail these experiments, however, I shall first make some remarks upon the composition and the peculiar changes to which milk is liable.

Sweet milk* is a perfect food, inasmuch as it contains all the alimentary constituents requisite for building up the diverse parts

* Sweet milk is always implied unless otherwise stated.

of the animal body; its different ingredients being also proportioned and suited to the requirements of the various tissues. This is clearly obvious and well exemplified in the fact that, although a child, or other mammal, receive for many months after birth no other food than its mother's milk, yet from this milk it forms its blood, muscles, nerves, fat, skin, bones, &c., &c. Hence it is manifest that milk is a rich organic fluid—a solution of the chemical compounds which form blood, muscles, nerves, &c., &c.—in fact, simply a solution of all the parts of the animal body.

Milk, also, as is necessary for so perfect a food, contains a large quantity of water—usually about 88 per cent. of its volume. Its other proximate constituents consist of casein—the substance which makes milk white, and which is capable of coagulation or curdling spontaneously, and by artificial means, and is susceptible of putrefaction; also, fat or cream, milk-sugar, or lactose, with various inorganic salts—as phosphates of lime, potash, &c.

New human and cow's milk when freshly drawn is alkaline, or neutral in reaction; were such not the case—*i.e.*, were it acid—it would be coagulated in the gland where it is formed from the blood, and hence could not possibly flow from the nipple or teat during sucking, or the process of milking.

Milk, after exposure to the air for a period varying with the temperature and purity of the surrounding medium, becomes more or less putrid, acid, and curdled—and hence, to a certain extent, deteriorated. These changes are accelerated by sultry weather with high temperature; but they are primarily caused by minute particles or shreds of decomposing organic matter, the presence of which may be quite imperceptible to the senses, falling on the milk from the air which surrounds it.

The first of these changes which milk undergoes is putrefaction of the casein, set up by contact with the minute decomposing particles referred to. The putrid casein then at once acts on the milk-sugar, changing it into lactic acid; this acid then reacts on the casein, curdling it, and imparting to the milk its sour taste. When a certain quantity of lactic acid is formed, it checks the further putrefaction of the casein, and for the time prevents the conversion of any remaining milk-sugar into lactic acid. Soon, however, the casein, being in excess of the milk-sugar, again putrefies and again causes any remaining milk-sugar to ferment; and the lactic acid again formed, again checks the putrefaction of the casein as before. Latterly, all the milk-sugar is changed into

lactic acid, but the putrefaction of the casein, held in abeyance for a time, again begins, and, finally, the milk becomes very sour and very putrid, and may now also contain capriolic, caprionic, and butyric acids.

Pure, new milk, then, is a delicately rich organic fluid containing a large percentage of water, and very prone to putrefy, to become acid, and to coagulate. That these deteriorating changes are caused by contact with atmospheric particles is shown by passing milk directly from the cow's udder, without exposure to the air, into a perfectly clean glass tube, and at once sealing it hermetically, when the milk remains unchanged for an indefinite time. It is also obvious that it is to prevent these changes that milk is intended by Nature to pass at once from the *mamma*, or milk-gland of the mother, into the stomach of her young; and that they are hastened by the milk being jumbled about on carts and railways, and exposed to the air by remaining on sale, and frequently transferred into different vessels.

That acid milk is injurious, at least to infants, is well-known to all medical men, who usually cause an aqueous solution of lime to be added to cow's milk to destroy any acidity, and make it either neutral or alkaline, as it is when newly drawn. Acidity of milk also implies putridity—and both, as shown, arise from impurities in the milk.

Milk may be acid and putrid to a degree not readily detected by taste or smell, and yet be capable of producing severe intestinal irritation in a child.

Colostrum, or the first few gallons of milk yielded by a cow, and probably by all mammals, after parturition, contains a variable quantity of albumen, and a peculiar purgative principle. This milk should not be sold to the public, as it has a greater tendency to putrefy, from its strong alkalinity and the presence of albumen, than ordinary milk, and also from its purgative action. It also mostly contains epithelium, casts of the lacteal tubes, pus cells, and granular matter, all of which are effete, or disease products.

The large percentage of water in milk makes it a most favourable medium for the putrefaction of the casein. This is shown by the fact that when the water is thoroughly separated from the casein by expression, the casein, now in the form of cheese, does not putrefy.

Again, of all natural bodies, water has the greatest solvent power—in other words, it will dissolve or absorb more substances

than any other fluid. Hence it follows that many bodies, whether as particles of dust, fluids, gases, or otherwise, coming in contact with milk, are apt to be dissolved in it, and render it impure.

Moreover, water will absorb or condense more gases than any other fluid, and that to a very great extent. Especially does it largely absorb gases and vapours of an offensive nature. Consequently such coming in contact with milk, will be dissolved in it, rendering it impure.

The offensive and unwholesome emanations from animal excretions—as from the urine, fæces, bowel gases, breath, and skin—are all absorbed by water, and hence by milk. Therefore milk kept in any apartment where a person sleeps or lives will quickly become impregnated with such emanations, and should the person chance to be diseased, the milk will be made more impure to a corresponding degree. The following experiments were made to ascertain whether milk would absorb the emanations of the undermentioned substances.

A portion of each substance was enclosed in a glass jar for eight hours, with a uniform quantity of milk, after which some of the milk was drawn off from the lower stratum with a pippette, then placed in a clean vessel, and afterwards tested as to whether it had become impregnated with any of the substance. With the exception of four of the experiments, the tests applied were smelling and tasting. In the four instances referred to chemical reagents were used :—

Coal gas, ...	Smell in milk	distinct.
Paraffin oil, ...	Do.	strong.
Turpentine, ...	Do.	very strong.
Onions, ...	Do.	do.
Tobacco smoke, ...	Do.	do.
Sulphuretted hydrogen, . .	Do.	strong.

The Milk gave a black precipitate with sulphate of iron and ammonia, indicating the presence of sulphuretted hydrogen.

Ammonia, ... Smell in milk moderate.

The Milk gave a black precipitate with sulphate of iron and sulphuretted hydrogen, indicating the presence of ammonia.

Sulphide of ammonium, . . Smell in milk very strong.

The Milk gave a black precipitate with sulphate of iron, indicating the presence of sulphide of ammonium.

Musk, ...	Smell in milk	faint.
Assafætida, ...	Do.	distinct.

Stale urine,	Smell in milk	faint.
Creasote,	Do.	strong.
Cheese (stale),	Do.	distinct.
Chloroform,	Do.	moderate.
Putrid fish,	Do.	very bad.
Camphor,	Do.	moderate.
Decayed cabbage,	Do.	distinct.
Human fæcal matter,	Do.	strong.

The Milk gave a black precipitate with ammonia and sulphate of iron, indicating the presence of sulphuretted hydrogen.

All the specimens of milk had a distinct odour of the substances to which they had been exposed 14 hours after removal from the glass jar.

The fact that milk absorbed the emanations of all the bodies enumerated shows how liable it is to taint; and although it may be said that it was, in many cases, not thereby rendered unhealthy, still it was undoubtedly in every case made impure.

The foregoing remarks may also be considered as applicable to cream, perhaps, as much as to milk; because, although cream contains less water, yet, from the albuminous nature of the envelopes of the cream corpuscles, I think it probably as susceptible of putrefaction as casein. I do not refer to buttermilk, as it is already in a state of putrefactive and fermentive change from impurities.

From the results of these experiments, I am strongly of opinion that sweet milk and cream are capable of imbibing from air or water, also of preserving, and perhaps even of reproducing the specific poisons, particularly of enteric fever, scarlet fever, and smallpox—and very probably, also, those of the other infectious diseases—and of communicating these diseases to persons susceptible of them, by their swallowing milk so contaminated. Hence there seems to be the greatest danger of milk poisoning from persons with infectious disease living near where milk is kept.

Many adherents of the vital or germ theory of disease assert that the germs of organisms found in putrid and fermenting fluids—and, I presume, by inference, those alleged to constitute infection—are capable of withstanding a temperature considerably beyond that of boiling water; yet some of these individuals with palpable inconsistency recommend that milk suspected to contain a specific organic poison should be boiled in order to destroy the germs of such poison. They assert, on the one hand, that a temperature of

212° Fahr. will not destroy the germs, and, on the other, recommend it as a means for their destruction. Now, unless it can be shown that milk when boiling exerts some special toxic action on alleged infective organisms not possessed by other fluids containing such organisms, one is forced to conclude that the boiling of infected milk does not destroy its alleged poisonous germs, or if it do, that of course such germs do not withstand a temperature above 212° Fahr.

But it has always far exceeded the utmost boundary of my conception to fancy that the germs of such alleged specific organisms, which are, apparently, as minute as the molecules of any chemical compound—for they have never been seen by the highest powers of the microscope—can withstand a temperature that would undoubtedly utterly destroy every form of tangible ovum and every kind of visible seed known. I will accept this statement when I am shown a hen hatching a chick from a hard-boiled egg, or a boiled potato sprouting.

It follows as a corollary to this belief that I agree with the persons referred to, that the boiling of milk *does* destroy any organisms in it, infective or non-infective; nay, I will go further by saying, that I believe the boiling of infected milk *will* annul or decompose so as to render inert its infection—assuming that to be, as I believe it is, merely putrid organic matter in a peculiar state of chemical synthesis.

VII.—*On Struthers' Process for Pulverising Diamondiferous Ore.*

By WALLACE FAIRWEATHER, C.E., Fellow of the Institute of Patent Agents.

[Read before the Society, 31st January, 1883.]

THE occurrence of diamonds in South Africa was first observed in 1867, when a large stone was found on a Boer's farm in Griqualand, West, and was purchased by Sir Philip Wodehouse, then Governor of the Cape Colony. In the year following, Mr. Gregory, a gentleman well acquainted with mining operations, was sent to prospect the Vaal and Orange River districts, but after traversing nearly 2,000 miles of territory, he returned to report not only that diamonds did not exist in Griqualand, but that the nature of the soil was such as to preclude the possibility of diamonds occurring in it.

Nevertheless, in January, 1870, exactly thirteen years ago, a prospecting party broke ground at Hebron, on the banks of the Vaal river, and finding diamonds in great numbers, established there what was known as the "River diggings."

The diamonds at the river diggings were found at the very surface, and were easily separated from the loose soil by washing and hand sorting—a plentiful supply of water from the river being available.

In the washing process the large stones were first separated by screening, and the residue washed with water in cradles to float off the clay and mud, leaving pebbles and smaller stones at the bottom, from which the diamonds were picked by hand.

Notwithstanding the great facilities for carrying on these operations on the banks of the Vaal, the river diggings were ultimately abandoned in favour of the higher plateau or open country in the neighbourhood of what is now the township of Kimberley, where valuable diamonds were obtained in the red surface soil.

The method at first adopted in treating the red soil for obtaining diamonds in this district, where water was not then obtainable, was to pass the earth through sieves or riddles. The smaller dross was rejected as valueless, and the larger stones and pebbles retained and spread upon tables to be examined. The occurrence

of a valuable diamond was not so common as to relieve the work of searching from tediousness, and when diamonds did occur among the pebbles, they were occasionally missed. Still the soil was so rich, that, it is said, diamonds have been found in the plaster covering the Boers' houses. When the upper soil was, to some extent, removed, the decomposed rock below the surface came to be treated. This soft rock was found to contain diamonds in greater proportions, but the mode of treatment was not materially different. The bottom of the beds of decomposed or softened stone was found to consist of hard rock of bluish colour. When this blue rock was reached it was generally considered time to abandon the "claim." Through time more particular attention was directed to the blue rock, and as it was found to be extremely rich in diamonds, it came to be worked almost exclusively, quarrying and mining being substituted for digging operations.

The "blue rock," or matrix of the diamond, is a hard breccia or conglomerate of limestone, shale, and basalt, intermixed with mica and other materials in smaller proportions, and cemented together by a calcareous clay or marl. This rock (of which I can only show you small samples) is easily recognised by its greenish blue colour, and the diamonds, when they occur, are, I need hardly say, no less readily recognisable.

In Griqualand the mines in which the blue rock occurs are all contained within an area of a few square miles. There are four mines—viz., Bultfontein, Du Beers, Dutoitspan, and New Rush or Kimberley—each resembling a small but deep lake entirely separated from its neighbours by what is known as the "Reef." This reef, which forms the containing walls or boundary of each mine, is composed of hard basaltic rock and shale. It contains no diamonds, and to the miners it is only a source of great trouble, danger, and expense. In the Kimberley mine a portion of it smoulders continuously; and it is with difficulty that negroes can be got to assist in its removal. (The burning reef is represented in one of the photographs of the Kimberley mine which are on the wall.) In the Orange Free State, about 80 miles farther south, there are two mines, Koffyfontein and Jägersfontein, which appear to be in nature similar to those in Griqualand. The area covered by each mine is very limited—the largest being about 30 acres, and the smallest 10 acres in extent. Each mine is divided into a large number of "claims" of about 30 feet square. (The division of Kimberley mine into claims is shown in the diagrams. The

square trimmed edges of the rock in some of the photographs also show the boundaries of "claims.")

The blue rock is obtained from the mine by blasting in a manner similar to that adopted in our quarries. The first difficulty that presents itself in dealing with the blue rock when blasted or quarried, is its removal outside the mine, which is in many places from 300 to 400 feet deep. A right of way from claims occupying a central position in the mine cannot be had across adjoining claims, unless when these claims are held by the same companies, and ordinary roadways, which served the purpose while the mining went on near the surface, are no longer available. The system adopted, therefore, is to carry the rock out of the mine by a series of wire tramways, on which large buckets or hutches are drawn by means of winding engines to the surface, where they are tipped into receiving-houses. (The wire tramways and winding gears are shown in some of the photographs of the mine.)

The blue rock, when outside the mine, cannot be simply screened and examined in the way that was applied to the treatment of the soft and loose diamond-bearing soil above. The ore has now to be taken away in hutches or wagons, and spread out on the ground or "floors"—which are merely extensive enclosures covering several miles—and there it is exposed to the action of the atmosphere, to alternations of heat and cold, and to rain, or when rain is scarce, to the watering-can. The ore is turned over at intervals, and the large pieces of rock are also partially broken up on the floors by the use of the pick and shovel.

This process—which is that now commonly employed—continues for a period varying from two to nine months, according to the nature of the ore and the season of the year. When the ore is somewhat softened, or is reduced to a friable state, it is ready for the next stages of collecting, breaking up by hand, screening, and washing. The washing process, as carried on at the mines, differs to some extent from that employed at the old river diggings. Rocking or oscillating cradles and large rotary washing-vessels are employed, and are actuated by hand or motive-power, according to the magnitude of the operations carried on.

Instead of using clear water, however, the broken ore is washed with a thin mud consisting of clay and water. The object of using this mixture for washing purposes is to facilitate the deposition of the diamonds. After considerable experience, the miners have found that, while the grosser impurities and light shale in the blue ground

remain long suspended in this muddy mixture, the diamonds and clean pebbles rapidly fall to the bottom, and can then be readily separated. The deposition of the diamonds does not appear to be due so much to superior specific gravity as to the clean surface of the stones compared with that of the shale and basalt in the ore. The washing process serves the purpose of separating the diamonds most admirably; and it is to the use of the washing machine that has been ascribed the rapid increase in the production of diamonds, which occurred immediately after its introduction to the Cape diamond fields eight or nine years ago.

There can be little doubt but that the introduction of suitable machinery in the earlier processes of treating the ore may be attended with equally beneficial results. Such at least was the expectation of Mr. Struthers when he conceived the idea of designing a machine for treating and pulverising the blue rock directly as it comes from the mine, and his expectations have been largely realised.

The process of spreading out, exposing, and breaking the ore on the floors is not only a most tedious and laborious one, but it is attended with the serious disadvantage that the material is subjected to very frequent handling during a prolonged period, and there is great risk of valuable diamonds being stolen. From authentic returns furnished to the mining companies it has been ascertained that nearly one-half of the diamonds in the ore are stolen while the ore is exposed on the floors. One of the main considerations, therefore, in introducing machinery to supersede the old process is to get rid of the inducement to theft which is offered by prolonged exposure of the ore.

Mr. Struthers is not the only practical mining engineer who has seen the advantage of substituting machines to do the heavy work which is at present performed by hand labour. Several other machines, such as pug mills, stamping presses, and crushing machines, have been tried, but they have not been successful. Their failure is, I think, partly owing to the fact that an action similar to that of the weather on the blue rock cannot be effected by machinery pure and simple.

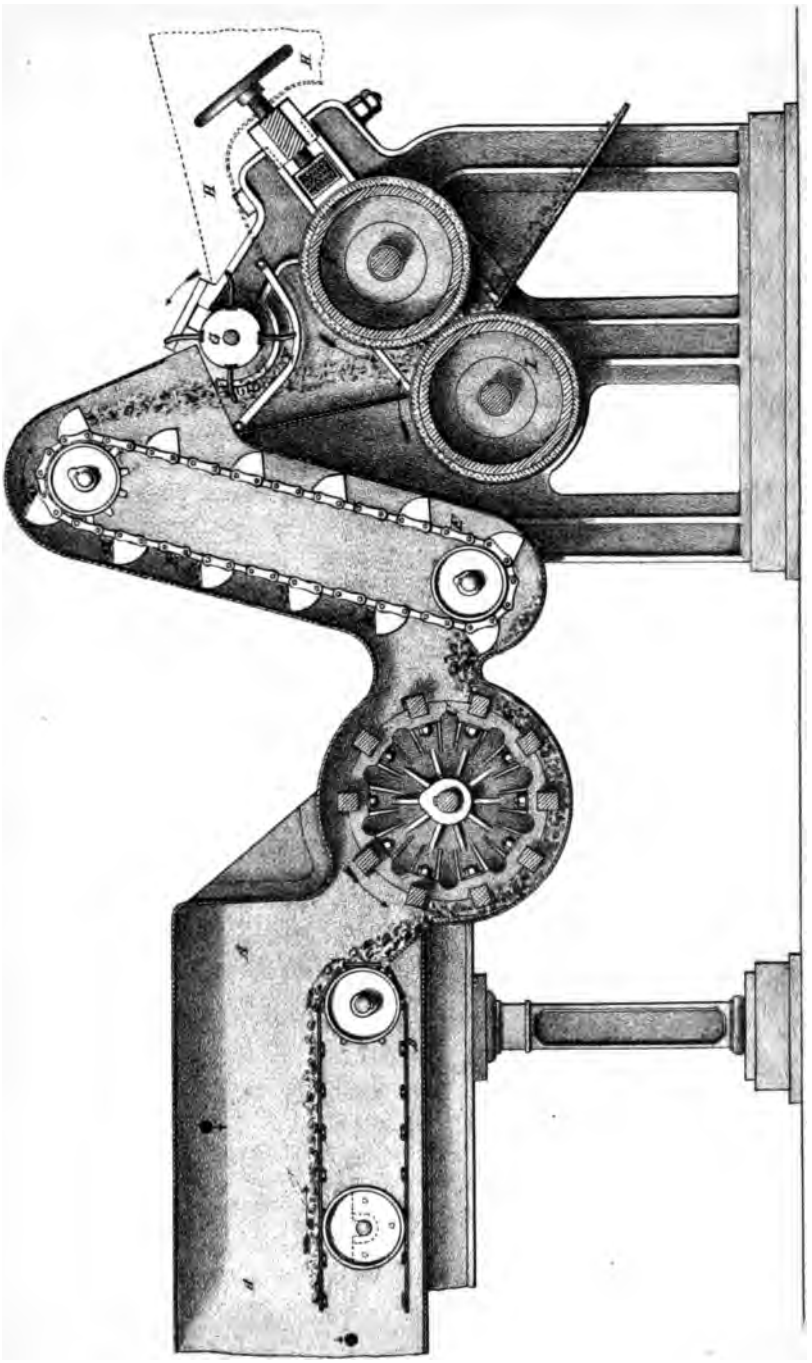
A process of treatment as nearly as possible analogous to that of prolonged exposure to the atmosphere must be combined with the disintegrating action of the machinery employed; and it is by taking this into account that Mr. Struthers has succeeded with his machine.

An essential condition of any process of treating diamondiferous ore is, that the hard blue rock should be first softened to a considerable extent, or rendered friable, so that, whatever may be the nature of the subsequent treatment by machinery, the action of the machine may not be alike on both the ore and the diamonds it contains. A simple crushing or breaking of the blue rock in its natural state has to be avoided, because the force that must be employed to break the hard rock would also tend to split the diamonds in it. But if a preliminary softening of the rock is effected, the machine has to perform a separating or sifting action rather than crushing or breaking. It may also be observed that diamonds, though extremely hard, are very brittle, and are readily split up if subjected to hard blows; but, on the other hand, while they are protected by a covering of softened rock, they are not liable to be damaged by the impact of even hard steel beaters.

As a preventative against theft—which is the bugbear of the old process—Mr. Struthers' machine has been designed to perform both the softening of the hard blue rock and the pulverising and sifting out or separating of the diamonds from the earthy matters, in one continuous operation, and that without the least need for handling the material under treatment.

The first part of the new process is to subject the lumps of blue rock, as they come from the mine, to the action of steam or hot water within a close vessel. The rock being calcareous, it has been found advantageous in some cases to add a small proportion of acid to assist in reducing the ore by decomposing the carbonate of lime present in it. The use of acid, however, involves the employment of a separate vessel to avoid corrosive action on the machine. In practice, therefore, the blue rock is only acted on by steam and the hot water resulting from the condensation of steam, which softens and reduces it sufficiently to render it fit for the disintegrating process which follows. The steam has an effect on the ore very similar to that of prolonged exposure to the weather, and it has the decided advantage that it can effect in a few minutes the work effected by several months' exposure of the ore on the floors.

The machine designed by Mr. Struthers to carry out his process is represented in longitudinal section in the drawing. It consists of a rectangular steaming tank or vessel, A, about 20 feet long, into which the diamond ore, in the broken lumps in which it comes from the mine, is fed through a close-fitting hopper at one end, and is delivered on to an endless travelling



band of lattice boards, B, supported on rollers. This endless band carries the ore slowly from one end of the tank to the other, and during its passage through the tank the ore is acted on by steam entering by pipes from a boiler, or by the exhaust steam of the engine which drives the machine. The endless band then delivers the ore, in a moist and softened state, to a beater or disintegrator, C, revolving rapidly within a close casing, D. The disintegrator is formed of iron blades, fitted with steel face plates, between which and corresponding steel plates fixed in the casing the pieces of ore are crushed and broken up. Sufficient space is, however, left between the beater and its casing for the largest size of diamonds to pass freely. Through the disintegrator the mass of broken earthy matter is delivered to the buckets of a chain elevator, E, by which it is raised and discharged on to a grating, F, over which a revolving rake or forked roller, G, is fitted. The softer earthy mass is pressed through the grating, which is about $1\frac{1}{2}$ inches wide, to let the largest diamonds pass, and any very large stones or pieces of the ore are thrown out by the teeth of the revolving rake, and pass through a shoot, H, from which they are removed and again treated in the machine. The main portion of the material passes down through the grating, and enters between a pair of large crushing rolls, I, I, which finally pulverise the earthy mass while allowing the diamonds to pass uninjured. In order to provide the necessary yielding action for the passage of diamonds of large size, one of the rolls is pressed against the other by strong springs, the pressure of which can be adjusted to suit the nature of the material under treatment. The rolls are also covered with vulcanised rubber, so that their surfaces may yield to local pressure of the diamonds or hard pebbles passing through. The rubber is protected by coils of wire wound round the rolls, or by articulated metal plates, which effectually crush the softened blue rock. The pulverised mass containing the diamonds falls down by a shoot, J, directly into the washing machine, which is of the ordinary construction. The pulverising machine is operated by means of a steam-engine, of 16 horse-power, placed at the side, and connected by gearing to the shafts of the revolving beater, the crushing rolls, and the various other moving parts.

By the use of this machine it is found that a much smaller quantity of water is required for washing than is the case when the ore is pulverised by the old process, and the finely ground clay in the earthy mass, when water is added, supplies, to a large

extent, the thin mud, by means of which the diamonds are sifted out. The earthy matter being well ground down, a larger proportion of it can be riddled or screened, if need be, and thrown away, without passing it into the washing machine. When this is to be done, a series of shaking riddles or revolving screens are interposed between the discharge shoot and the washing machine.

The first machine of the kind described was erected at Kimberly mine by the patentee, Mr. A. J. Struthers, nearly a year ago, and during the time that has since elapsed it has been fully tested. The experience gained by the use of the machine shows that, while the earthy matters are effectually pulverised, the diamonds in the ore are not in any way damaged. I am assured that diamonds have been repeatedly put through the empty machine without sustaining injury. The most satisfactory testimonial in its favour, however, comes from the chairmen and managers of the mining companies in Griqualand, who have signified their approval of the machine and of the new process of treatment introduced by Mr. Struthers. On the other hand, the tests made in working the first machine have also suggested to the inventor several improvements in construction, which are being adopted in making machines for future use. The new process of treatment by steam leaves nothing to be desired. The problem of treating the hard blue rock by means of machinery has been satisfactorily solved, and it is only necessary that machines of this kind be generally introduced to enable the output of the diamond fields to be greatly increased.

The capacity of the first machine is from 600 to 1,000 loads per working day, and three men only are required to attend to it. To perform the same amount of work by hand labour, and by the old process of open-air exposure, the services of a much larger number of men are required.

The quantity of ore treated annually in the South African diamond fields may be roughly stated at twenty millions of tons. To carry on the work of treating and pulverising all this ore, Mr. Struthers estimates that one hundred machines would be required. The total cost of these machines, delivered on the ground, would not exceed a quarter of a million sterling.

The cost of treatment of the ore by hand labour averages seven or eight shillings per ton in the Kimberley mine, where the rock dealt with is very hard. In Du Beers and Dutoitspan the cost of treating the ore is considerably less, but its value is

not nearly equal to that of the Kimberley mine, which averages from £2 to £6 per ton.

By the use of Mr. Struthers' machine, the cost of treating the Kimberley ore is reduced to two shillings a ton. At this figure the entire production of the mines could be treated at an annual outlay of £2,000,000, while the expenditure for hand labour by the old process of treatment is at least double that sum. The saving to the miners resulting from economy of treating the ore by Mr. Struthers' process, as compared with hand labour, would be equalled, if not even surpassed, by the almost entire suppression of diamond stealing which the adoption of the new machines would bring about. By doing away with the use of the floors, opportunities for theft would not occur, and illicit diamond dealing, which is at present extensively carried on in South Africa, would be practically abolished. The saving from this source alone is estimated at nearly £2,000,000 annually.

Against that must be put a charge for royalty on the production of the machines. So far, the rate charged on this account has been one shilling per load, which, if the saving effected be taken into consideration, is very moderate. The machine erected by Mr. Struthers at Kimberley is earning in royalty about £30 a day, or nearly £10,000 a year. A corresponding profit from the entire number of machines required for treating the ore of the mines in South Africa would yield nearly £1,000,000 annually, which, though a large sum, is probably not more than half the amount at present divided each year between the diamond thieves and illicit dealers who buy up the stolen diamonds.

In giving these figures, I have not taken into account the probable extension of diamond mining in South Africa, nor have I even assumed that the new process can be applied in the mines of India, of Brazil, and of Australia. There is, however, no good reason that I know of why the ore from the older diamond mines should not be capable of treatment with equal advantage by Mr. Struthers' process; and there is also little reason to believe that the South African blue rock is confined within six little pipes or lakes.

VIII.—*On the use of Litmus, Methyl Orange, Phenacetolin, and Phenolphthaleïn as Indicators.* By Robert T. Thomson.

[Read before the Chemical Section, 22nd January, 1883.]

The number of indicators which have been proposed to supersede litmus is now very great, but none, as far as I am aware, have been thoroughly tested as regards their efficiency in presence of the impurities which constantly occur in the alkaline hydrates and carbonates of commerce. There is no lack of information to be obtained concerning the high tinctorial power of these indicators compared with that of litmus, and their delicacy when employed in the determination of alkalis in solutions of the pure hydrates and carbonates; but on the question of their value in presence of sulphites, thiosulphates, sulphides, phosphates, silicates, aluminates, etc., little or no attention has been bestowed.

In the following paper are detailed the results of a series of experiments I carried out with the view of testing, in as complete a manner as possible, the merits of litmus, methyl orange, phenacetolin, and phenolphthaleïn as indicators in the estimation of alkalis and certain free acids. Instead of taking these indicators in succession, and recording all the tests made with them, I have considered it preferable to take the substances which were tested by the standard acid or alkali, and state the result obtained with each indicator. By this means a close comparison of the behaviour of the different indicators with the same substance will be secured.

The tests were made in such a way that the solution employed would measure about 100 c.c. when the end-reaction was observed. The strengths of the indicator solutions (·5 c.c. of which was used for every experiment) were so arranged that equal volumes of each gave, as nearly as could be judged from their different tints, the

same intensity of colour at the point at which the change caused by the addition of excess of acid or alkali was just complete.

1.—Delicacy of the indicators in absence of interfering agents.

This was tested by adding the ·5 c.c. of the indicator solution to 100 c.c. of distilled water, and finding how much decinormal acid or alkali (1 c.c. = ·0031 gram. Na_2O or ·004 gram. SO_3) was required to change the colour.

Litmus.—This indicator, as is well known, is naturally blue, and remains so in presence of alkalis and alkaline carbonates, but changes to red when a slight excess of acid is added. The litmus solution employed contained 20 grams. of the dry extract per litre. Half a c.c. of this was mixed with 100 c.c. of distilled water, and decinormal sulphuric acid added from a burette, drop by drop, till no further alteration in colour was observed. To accomplish this ·5 c.c. of the acid was consumed. This is equal to ·05 c.c. (about one drop) of normal acid, which is the strength usually employed in alkalimetric tests.

Methyl orange.—It is soluble in water with formation of an orange yellow liquid, which is unchanged in colour by alkalis or alkaline carbonates and bicarbonates, but is transformed to a deep pink by a mineral acid. The solution employed contained ·15 gram. of the methyl orange per litre, and ·5 c.c. of decinormal acid was required to effect a complete change in the colour, when tested in exactly the same way as the litmus solution. It is thus on an equality with litmus as regards delicacy in absence of all salts.

Phenacetolin.—This substance is soluble in alcohol with formation of a dark brown liquid, which gives, with the hydrates of potassium and sodium, even in presence of carbonate, a scarcely-perceptible yellow, with ammonia and the normal alkaline carbonates a dark pink, with the bicarbonates a much more intense pink than with the normal carbonates, and with mineral acids a golden yellow colour. The solution employed contained 2 grams. of phenacetolin per litre, and was tested by decinormal carbonate of sodium, of which ·1 c.c. was required to produce a decided change from a faint brown tinge to a dark pink.

Phenolphthaleïn.—This indicator gives rise to a fine red colour in presence of alkaline hydrates and carbonates, but with bicarbonates (in absence of normal carbonates) and free acids no colour is produced. Phenolphthaleïn is almost insoluble in water, but is

readily soluble in 50 per cent. alcohol. The solution used contained ·50 gram. per litre, and was of a pale yellow colour, which was probably due to a slight impurity. When tested under the conditions observed in the case of the other indicators, ·1 c.c. of decinormal hydrate of sodium caused a sudden transformation, the colourless solution becoming red.

In the following Table (I.) will be found a summary of the results given above.

TABLE I.

Showing the delicacy of the indicators in the absence of interfering agents.

Amount of distilled water used for each test, ... 100 c.c.
Amount of indicator solution used for each test, .. 0·5 c.c.

Name of Indicator.	Grams. of Solid Matter per litre of Indicator solution.	Amount of Decinormal Acid or Alkali required to change colour of Indicator.	
Litmus, . .	20·0	·5 c.c.	H_2SO_4
Methyl orange, .	·15	·5 ,,	,,
Phenacetolin, .	2·0	·1 ,,	Na_2CO_3
Phenolphthalein, .	·5	·1 ,,	NaHO

II.—Application of the indicators to the determination of soda existing as hydrate with a small proportion of carbonate.

The solution of caustic soda employed was of normal strength, and each test was made with 50 c.c., which thus contained 1·55 gram. of available soda. The soda existing as carbonate in this quantity was ·024 gram. and was estimated by precipitation with chloride of barium.

Litmus.—When this indicator was used exactly 50 c.c. of normal sulphuric acid were consumed. The solution was, of course, boiled thoroughly after each addition of acid, especially when near the neutral point, and only a single drop was required to effect the end-reaction.

Methyl orange.—The great advantage claimed for methyl orange over litmus is that with the former no boiling is required, as carbonic acid has no effect on the colour. On making several determinations of soda with this indicator, I found that its

delicacy was by some means considerably impaired, as the pale yellow colour became just perceptibly tinged with pink when 49·95 c.c. of the normal acid were added. The change in colour was very decided when 50, but was not fully developed till 50·15 c.c. were consumed. In these cases ·2 c.c. of the acid was necessary to bring out the full intensity of colour, while ·05 c.c. produced the same result in absence of interfering agents. It would be naturally expected that if half the quantity of methyl orange were used, a proportionately more delicate end-reaction would be secured, but at least ·15 c.c. of the normal acid was required to occasion the alteration in tint. Again, the same expectation might reasonably be entertained with regard to varying the proportions of soda, but I found that when ·775 gram. of soda was tested ·15 c.c., while with 3·1 grams. of soda, ·25 c.c. of the test acid was indispensable in effecting the complete transformation. It is evident that this extension of the end-reaction over from ·15 to ·25 c.c. of normal acid must be due, either to the liberated carbonic acid, or to the salt of sodium produced by the action of the acid on the hydrate and carbonate of sodium. That it is solely owing to the latter cause I shall show when the action of the neutral sulphates, chlorides, and nitrates of the alkalis is under consideration. On looking over these results the question arises, At what point is the estimation of alkali, when methyl orange is used as indicator, to be reckoned as finished? The point I have adopted is that at which the first *decided* change in colour is apparent, and this end-reaction coincides exactly with that of litmus. The intensification of the colour by the further addition of acid serves as a confirmation of the first reading. Greville Williams, in a paper which appeared in the *Chemical News*, xxxix., 98, recommends for each determination the use of from ·1 to ·2 c.c. of a solution containing ·1 gram. of methyl orange per litre. The larger of these quantities is about one-fourth of that which I have employed, and when excess of acid is added gives a very faint pink colour, which is sensibly less intense in presence of much sulphate of sodium. It is obvious, however, that the amount of the indicator solution used must be varied according to the volume and colour (if any) of the solution in which the alkali is to be determined.

Phenacetolin.—This indicator was introduced by Degener for use in the determination of the respective proportions of hydrate and carbonate of sodium in the same solution, and was tested by

Prof. Lunge, whose results will be found in the *Jour. Soc. Chem. Industry*, i., 55.

To determine the hydrate of sodium the normal acid was added till the scarcely perceptible yellow colour gave place to a rose-pink, which remained permanent for a few minutes at least. Two tests gave respectively 49·1 and 49·2 c.c. of acid consumed, which are equal to 1·523 and 1·526 gram. of soda existing as hydrate, as against 1·526 obtained by deducting the soda existing as carbonate (which was determined by chloride of barium) from the total soda. It must be carefully borne in mind that the rose colour should be permanent, for it may be developed by adding a drop of the acid, even when there is still a little hydrate present, and then fade slowly away. The first reading can be confirmed by adding a drop or two more acid, which should render the colour more intense.

To find the proportion of soda existing as carbonate the addition of acid was now continued. The colour at first was intensified, then became mixed with yellow, and finally all the pink tinge was eliminated, and a golden yellow was produced. For each test 50 c.c. of the normal acid were consumed, thus giving in the one case ·9 c.c. for the soda as carbonate, and in the other ·8 c.c., showing respectively ·027 and ·024 gram. of soda existing as carbonate, as against ·024 estimated by chloride of barium. A much sharper end-reaction is obtained by boiling off the carbonic acid after each addition of acid when determining the portion of soda existing as carbonate.

Phenacetolin is not adapted to the estimation of small quantities of hydrate in presence of a large proportion of carbonate of sodium or potassium, as is evident from the following test. To a solution containing 2·65 gram. of carbonate of sodium and ·04 gram. of hydrate of sodium in 100 c.c., phenacetolin was added, but even after an hour had elapsed the dark pink colour did not disappear, as it should do if the process were of any value.

Phenolpthalein.—This indicator, which seems first to have been employed by Luck in that capacity, can also be used for the determination of the proportion of hydrate and carbonate of sodium in the same sample. The method of procedure is to add the normal acid to the cold alkaline solution till the red colour is discharged, taking care, by using a dilute solution and keeping the point of the burette in the liquid, that no carbonic acid escapes. The point at which the colour is dispelled is when all the hydrate is

neutralized, and the carbonate has been converted into bicarbonate according to the following equation:—

$$2Na_2CO_3 + H_2SO_4 = 2\ NaHCO_3 + Na_2SO_4.$$

By this means the whole of the soda existing as hydrate and half the soda as carbonate is determined. The number of c.c. consumed is now noted, and the estimation continued, boiling thoroughly after each addition of acid to decompose the bicarbonate of sodium, and thus bring back the red colour. It is preferable, as pointed out by Warder in his paper in the *Chem. News*, xliii., 228, to add excess of normal acid, boil off the carbonic acid, and titrate back with normal caustic soda. The results of several experiments gave 49·6 c.c. of normal acid consumed for the hydrate and half the carbonate of sodium, and 50 c.c. for the total available soda, or, in other words, ·8 c.c. for the carbonate and 49·2 for the hydrate. These results agree almost exactly with those obtained by the estimation of the carbonate of sodium by barium chloride, and with the use of phenacetolin as indicator. It must be noted that the more carbonate of sodium there is present the less delicate will the end-reaction be, as the red colour gradually fades away during the first portion of the titration. It is also evident, from the nature of the process, that this method is quite unreliable for the determination of a small quantity of hydrate of sodium in presence of a large proportion of carbonate of sodium.

TABLE II.

Showing results obtained by each indicator when used in the determination of soda in caustic soda containing a little carbonate of sodium.

Soda, existing as hydrate, employed, ... 1·526 gram.
Do., do. carbonate, do., ... ·024 ,,
Total soda employed, ... 1·550 ,,

Name of Indicator.	Grams. of total Na_2O found.		Grams. of Na_2O as hydrate found.		Grams. of Na_2O as carbonate found.	
Litmus, . . .	1·55	1·55	..		...	
Methyl orange, .	1·55	1·55	..		...	
Phenacetolin, . .	1·55	1·55	1·523	1·526	·027	·024
Phenolphthaleïn, .	1·55	1·55	1·526	1·526	·024	·024

III.—Estimation of available potash in caustic potash.

It is quite unnecessary for me to give any details of the results of the experiments made under this head. Litmus and methyl orange can be used for the determination of the total available potash, and phenacetolin and phenolphthaleïn for the estimation of the respective proportions of hydrate and carbonate of potassium, with as great accuracy as in the case of the caustic soda.

IV.—Estimation of ammonia existing as hydrate.

The liquor ammonia used for the following tests did not contain an appreciable quantity of carbonate, and was free from other impurities. It was diluted with an indefinite quantity of water, and 50 c.c. of the dilute sample were employed for each determination. This quantity, according to a result obtained by converting the ammonia into chloride of ammonium and drying at 100° C., contained ·547 grams. of ammonia (NH_3).

When litmus, methyl orange, or phenacetolin was used, exactly 32·4 c.c. of normal sulphuric acid were consumed, which are equal to ·550 gram. of ammonia. The end-reactions in each case were quite as delicate as with caustic soda. As phenacetolin produces with ammonia the dark pink colour characteristic of its reaction with the carbonates of sodium and potassium, and not the faint yellow formed with the hydrates of these metals, the respective proportions of hydrate and carbonate of ammonium cannot be determined by titration in presence of this indicator.

In the two determinations made with phenophthaleïn as indicator 31·5 c.c. and 31·4 c.c. of the normal acid were consumed. After 25 c.c. had been added the colour began to fade away slowly, and was fully discharged at the point mentioned. These results show respectively ·535 and ·533 gram. of ammonia, and are so far below the truth as to be equal to about 3 per cent. of the whole ammonia present. It is, therefore, perfectly plain that phenolphthaleïn is utterly useless for indicating the end-reaction in the estimation of ammonia. This anomalous behaviour of phenolphthaleïn is due to the action of the salt of ammonium which is formed, and which destroys the red colour produced by the ammonia when the proportion of the latter becomes small. That this is the true explanation will be shown when the effect of the neutral salts of ammonium on the indicators comes to be examined.

TABLE III.

Determination of ammonia existing as hydrate.

Ammonia (NH_3) employed for each test, ... ·547 grams.

Name of Indicator.	C.C. of Normal Acid consumed.	Grams. of NH_3 obtained.
Litmus,.	32·4	·550
Methyl orange, . . .	32·4	·550
Phenacetolin, . . .	32·4	·550
Phenolphthaleïn, . . .	31·5—31·4	·535—·533

Before writing the above, I had not met with any mention of phenolphthaleïn as an indicator for the estimation of ammonia, but, quite recently, it has been recommended for this purpose by Richter, in a paper on a "New volumetric determination of potassium bichromate, and its use as a standard for caustic alkalies" (see *Chem. News*, xlvii., 19). The process he has devised may be thus briefly described. To the caustic soda, potash, or ammonia solution, which has been previously coloured with plenolphthaleïn, add standard dichromate of potassium till the reddish-yellow colour produced is changed to a full yellow. At this point the alkali is neutralized, a monochromate of the alkali or alkalies is formed, and the reddish tinge due to the presence of the phenolphthaleïn in the alkaline solution is discharged when the least excess of acid chromate is consumed. The quantities advised for use are such that the solution in which the titration has been accomplished should measure 150 or 200 c.c., and contain about 1 gram. of the monochromate of potassium. A solution of this salt, of the strength mentioned, is to be used as a comparison in deciding at what point the end-reaction occurs. Following these instructions as closely as possible, I prepared a decinormal solution of potassium bichromate (14·76 grams. per litre), and, also, decinormal solutions of caustic soda, potash, and ammonia, the alkali liquors being tested against decinormal sulphuric acid. 50 c.c. of the soda solution were transferred to a beaker, diluted with 50 c.c. of water, coloured with phenolphthaleïn, and the decinormal bichromate solution added from a burette. The fine red tint soon changed to reddish-yellow, which lost little or none of its intensity till it nearly reached the neutral point. The end-reaction

was thus easily observed, especially when compared with the solution of monochromate of potassium of nearly the same strength as that operated upon. It must be carefully noted, however, that the change in colour is not instantaneous, as it is by titration with a mineral acid, so that when the test is nearly finished, a minute or two must be allowed to pass after each addition before coming to any conclusion as to whether the end-reaction has taken place. Otherwise a high result will be the consequence. The results of two tests were, that 50 and 50·1 c.c. of the decinormal bichromate were consumed, which are as near the truth as possible.

With regard to the determination of the potash, it is sufficient to mention that the results were substantially the same as those obtained with soda.

In estimating the ammonia in 50 c.c. of the decinormal solution of ammonia, the addition of the bichromate produced at first the reddish-yellow colour, which slowly disappeared on further addition, and gave place to the full yellow when 45·7 c.c. had been consumed in the one case, and 46 c.c. in the other. This gives a result so much below the truth, as to be equivalent to 8 per cent. of the whole ammonia present. From these results it is quite plain that Richter has not tested ammonia specially with phenolphthaleïn as indicator, but has simply assumed that it would act in precisely the same manner as potash and soda.

TABLE IV.

Comparison of results obtained in the estimation of alkalies by Richter's bichromate and the ordinary acid methods, phenolphthaleïn being the indicator.

Amount of soda used for each test, ... ·1550 gram.
Do. potash do., ... ·2355 do.
Do. ammonia do., ... ·0850 do.

Name of Alkali determined.	C.C. of $\frac{N}{10}$ $K_2Cr_2O_7$ consumed.	Gram. of Alkali obtained.	C.C. of $\frac{N}{10}$ acid consumed.	Gram. of Alkali obtained.
Soda (Na_2O), .	50·1	·1553	50·1	·1553
Do., .	50·0	·1550	50·1	·1553
Potash (K_2O), .	50·1	·2359	50·1	·2359
Do., .	50·2	·2363	50·0	·2355
Ammonia (NH_3),	46·0	·0782	47·1	·0800
Do., .	45·7	·0777	46·9	·0797

V.—Determination of alkalies existing as carbonate and bicarbonate.

It is not worth while going fully into the results of the tests made on this part of the subject. As almost all the noteworthy points have been already mentioned, I will just note a few necessary precautions. As is well known, litmus can be used in the direct estimation of soda and potash existing as carbonate or bicarbonate by an acid, but can only be applied to the determination of ammonia in that form when excess of acid is added, the solution boiled to expel carbonic acid, and titrated back with an alkali. The same remarks apply to phenacetolin.

Methyl orange can be employed equally well in the estimation of alkali in any of the alkaline carbonates, but special mention may be made of its application to the determination of ammonia in the commercial carbonate. This substance is a compound of bicarbonate and carbonate of ammonium, and when dissolved in water the latter of these salts takes up the elements of water and produces normal carbonate of ammonium. The sample tested did not contain any impurities except water, and 2·5 grams. converted into chloride and dried at 100° C. showed ·725 gram. of ammonia, while two experiments made with 2·5 grams., which consumed 43·1 and 43·05 c.c. of normal sulphuric acid, gave respectively ·732 and ·731 gram. of ammonia.

Phenolphthaleïn, as stated before, cannot be used for the estimation of ammonia, and in the determination of soda and potash existing as carbonate or bicarbonate (the latter giving no colour with this indicator till decomposed by boiling), a somewhat tedious boiling is required unless excess of acid be added, the solution boiled and titrated back with caustic soda.

VI.—Behaviour of the indicators with the sulphates, nitrates, and chlorides of the alkalies.

Having considered the use of the indicators for the estimation of the alkalies when pure compounds are operated upon, we now come to the behaviour of the indicators with the common impurities present in commercial samples. This section, however, is chiefly concerned with the action (if any) of the neutral salts produced during titration. Litmus and phenacetolin are quite as delicate in presence of quantities of the sulphates, nitrates, and chlorides

of sodium, potassium, and ammonium equivalent to 1·55 gram. of soda (Na_2O) per 100 c.c. When these amounts of these salts were tested with the volume of methyl orange solution used in the foregoing experiments, it was found, as has been already stated, that about ·2 c.c. of normal acid was required to bring out the full pink colour as against ·05 c.c. when distilled water only was employed, although a distinct change was produced with ·05 c.c. in the former case. On the other hand, the delicacy of phenolphthaleïn is not affected by the salts of sodium and potassium mentioned above, but quantities of sulphate, nitrate, and chloride of ammonium, equivalent to ·85 gram. of ammonia per 100 c.c., required about 1·5 c.c. of normal caustic soda to produce even the faintest red colour, showing that ammonia and its salts must be carefully excluded when this indicator is made use of.

VII.—Effect of the sulphites of the alkalies.

A sample of ordinary normal sulphite of sodium was selected, tested for impurities, and the sulphurous acid, sulphuric acid, and soda determined to make certain that it was of the proper composition. This was found to be the case, and a solution was prepared of which 50 c.c. (the amount used for each test) contained 3·15 grams. of sulphite of sodium. This is equal to 1·55 gram. of soda (Na_2O).

Litmus.—On adding the normal acid to the portion tested with this indicator, the solution remained quite blue till about 12 c.c. had been added, but after that it became purple and slowly passed into the red. The end-reaction was observed by comparing with a solution containing the same quantity of litmus reddened. 24·9 c.c. were consumed, which is equal to ·771 gram. of soda, or very nearly half that contained in the sulphite of sodium. When boiled, the colouring matter is destroyed.

Methyl orange.—In this case 25·1 c.c. of the normal acid were consumed, which is equal to ·778 gram. of soda—a result slightly higher than that obtained by litmus, but still practically the same. The end-reaction was, unlike that of litmus, very sharp and decided.

Phenacetolin.—With phenacetolin the result was exactly the same as that procured with methyl orange; but, as in the case of litmus, the colour changed so gradually that the end-reaction was not very sharply defined.

Phenolphthaleïn.—Sulphite of sodium is practically neutral to phenolphthaleïn, but, as has been shown, it is strongly alkaline

to the other three indicators. Only ·2 c.c. of normal acid was necessary to discharge the red colour in the cold, but when boiled 4 c.c. were required. On cooling and titrating back, 3·8 c.c. of normal alkali were consumed; so that when this method is employed, the practical neutrality of sulphite of sodium may be depended upon, provided too much acid is not added before boiling. If a large excess of acid were used the boiling would expel sulphurous acid, and a high result would be the consequence.

It need only be added that potassium and ammonium sulphite act towards these indicators in the same way as the sodium compounds, except in the case of the ammonium salt with phenolphthaleïn, which cannot be used in presence of ammonium compounds.

TABLE V.

Results obtained in the titration of sodium sulphite with normal acid.

Amount of Na_2SO_3, used for each test, 3.15 grams.
Equal to Na_2O, ... 1·55 ,,

Name of Indicator.	C.C. Normal Acid consumed.	Grains Na_2O obtained.
Litmus, ...	24·9	·772
Methyl orange, ...	25·1	·778
Phenacetolin, ...	25·1	·778
Phenolphthaleïn (cold), ...	·2	·006
Do. (boiled), ..	4·0	·124

VIII.—Effect of thiosulphate of sodium.

This salt, which is known better as the hyposulphite of soda, is perfectly neutral to litmus, methyl orange, phenacetolin, and phenolphthaleïn.

IX.—Effect of sulphide of sodium.

To obtain pure normal sulphide of sodium a solution of sulphuretted hydrogen was prepared, the strength of which was determined by oxidation in an alkaline solution with peroxide of hydrogen, and precipitation with chloride of barium. Exactly enough hydrate of sodium was now added to form Na_2S, and the

solution made up to such a volume that 50 c.c. (the quantity operated upon) contained ·284 grams. of the sulphide.

Litmus.—When thoroughly boiled after each addition of acid to expel the sulphuretted hydrogen, an excellent result was obtained, 7·2 c.c. of normal acid being consumed. This is equal to ·280 grams. of sulphide of sodium.

Methyl orange.—With this indicator the same number of c.c. of acid was consumed as with litmus. The liberated sulphuretted hydrogen had evidently no effect on the colour, as the end-reaction was quite sharp. This has been pointed out by Lunge.

Phenacetolin behaves in much the same way as litmus, the boiling off of the sulphuretted hydrogen being necessary to the obtaining of a decided change in colour when the end of the experiment is reached. The result was the same as that obtained with litmus.

Phenolphthaleïn gave rise to the characteristic red colour with the sulphide of sodium; but this colour was discharged after the addition of 3·55 c.c. of normal sulphuric acid. This is practically equal to half of the sodium sulphide, and shows that the sodium hydrogen sulphide—which is formed by the combination of the normal sulphide with the liberated sulphuretted hydrogen—is neutral to phenolphthaleïn. On boiling the solution the red colour returned, and, altogether, 7·15 c.c. of the acid were consumed—the whole of the sodium sulphide being thus estimated.

Potassium and ammonium sulphides have exactly the same effect as the sodium compound, always excluding phenolphthaleïn with regard to the ammonium salt.

TABLE VI.

Results obtained in the titration of sodium sulphide by normal acid.
Amount of Na_2S employed for each test, ... ·284 gram.

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2S found.
Litmus,.	7·2	·280
Methyl orange, . . .	7·2	·280
Phenacetolin, . . .	7·2	·280
Phenolphthaleïn (cold), .	3·55	·138
Do. (boiled), .	7·15	·278

X.—Effect of the phosphates of the alkalies.

As the normal phosphate of potassium is generally found to the extent of one or two per cent. (it has even been found as high as seven per cent.) in commercial carbonate of potash, it is a matter of great importance to know what proportion of the potash, existing as phosphate, is determined by standard acid. I found that the phosphates of potassium, sodium, and ammonium acted in the same manner towards the indicators when titrated with standard acid, and will, therefore, only quote the double series of experiments made—the one with normal sodium orthophosphate (Na_3PO_4), and the other with the ordinary disodium hydrogen orthophosphate (Na_2HPO_4). The crystallized form of the former of these salts was prepared by dissolving a weighed quantity of the latter in boiling water, adding the proper proportion of hydrate of sodium, and allowing to crystallize out. After re-crystallizing both of these phosphates, a portion of each was ignited to obtain the real amount of dry salt in each, and solutions made of such a strength that 50 c.c. contained in the one case 2·05 gram. Na_3PO_4 (equal to 1·162 gram. Na_2O), and in the other 1·775 gram. Na_2HPO_4 (equal to ·775 gram. of Na_2O).

When *litmus* was used in the titration of the normal phosphate, the blue colour remained intact until about 16 c.c. of the normal sulphuric acid were added, when it became purple, and, on further addition, slowly passed into red, the change being complete at about 24·9 c.c. This is equal to ·772 gram. of soda, which is practically two-thirds of the total soda. The point at which the red colour was fully developed could not be ascertained with any degree of accuracy, even when a solution of reddened litmus was used for comparison, as the change was so very gradual. The mono-acid phosphate consumed 12·4 c.c. of the standard acid, thus agreeing with the result of the normal phosphate.

Methyl orange gives as delicate an end-reaction as with hydrate of sodium. The results were slightly higher and nearer the truth than those obtained with litmus, 25·05 c.c. being required in the one case and 12·6 in the other.

Phenacetolin.—With this indicator the same number of c.c. were necessary as with litmus, and, like the latter, changes gradually in colour, so that the point at which excess of acid is added is somewhat difficult to catch. There is, however, a peculiar phenomenon to be noticed with regard to this indicator. The normal

phosphate, like hydrate of sodium, only brings out the scarcely perceptible yellow colour; but, after the addition of about 11 c.c. of the normal acid, the permanent pink colour is formed. In fact, the first-named salt acts towards phenacetolin as if it were a mixture of hydrate and the mono-acid phosphate of sodium. The latter salt produces the pink colour at once.

Phenolphthaleïn again acts in an entirely different way to the other indicators. We have seen before that $NaHCO_3$, NaHS, and Na_2SO_3 are neutral to this indicator, and to these must now be added Na_2HPO_4; while $NaHSO_3$ and NaH_2PO_4 are neutral to litmus, methyl orange, and phenacetolin—$NaHCO_3$ and NaHS being alkaline, and not requiring to be decomposed by boiling before determining the alkali in them by test acid. It will be observed that, in each case, there is exactly an atom of sodium of difference, the phenolphthaleïn being invariably the weaker indicator.

In titrating the normal phosphate, 12·65 c.c. of the test acid were required to discharge the red colour in the cold, and 13·7 c.c. in the boiling solution, the mono-acid phosphate requiring only ·25 in the cold and 1·4 in the hot. In each case, on cooling and titrating back with caustic soda, the same result as was obtained at first in the cold solution was brought out. These results show that when phenolphthaleïn is employed, one-third of the soda in normal phosphate of sodium is estimated by standard sulphuric acid, and only a trifling portion of that existing as the mono-acid phosphate.

TABLE VII.

Results obtained in the titration of normal sodium phosphate and disodium hydrogen phosphate by normal acid.

Na_3PO_4 used for each test,	...	...	..	2·050
$=Na_2O$,, ,,	...	...	..	1·162
Na_2HPO_4 ,, ,,	..	...	...	1·775
$=Na_2O$,, ,,	..	...	...	·775

Name of Indicator.	Na_3PO_4		Na_2HPO_4	
	C.C. Normal Acid consumed.	Gram. of Na_2O found.	C.C. Normal Acid consumed.	Gram. of Na_2O found.
Litmus, ...	24·9	·772	12·4	·384
Methyl orange, . .	25·05	·776	12·6	·390
Phenacetolin (first change),	11 0	·341	...	...
Do. (second ,,),	24·9	·772	12·4	·384
Phenolphthaleïn (cold), .	12·65	·392	·25	·008
Do. (boiled),	13·7	·425	1·4	·043

XI.—Effect of silicate of sodium.

A preliminary test was made of the value of litmus for the estimation of soda in silicate of sodium, by taking a quantity of hydrate of sodium of known strength, dissolving some silica in it, and then determining the soda. The exact amount of soda used was found, and the estimation made by litmus was taken as the standard of comparison with the results obtained with the other indicators. Five grams. of commercial liquid silicate of soda was employed, and 15·05 c.c. of normal acid was consumed with litmus as indicator, the end-reaction taking place with great distinctness.

With *methyl orange* also a very distinct end-reaction was obtained, and 15·1 c.c. was consumed—a result closely corresponding with the former one.

Phenacetolin gave a dark pink colour with the silicate of sodium, but this became yellowish towards the end of the test, and the change was not very distinct. 15 c.c. of the acid was necessary, which does not materially differ from the quantities obtained with litmus and methyl orange.

Phenolphthaleïn.—The red colour produced by the phenolphthaleïn was slowly destroyed on running the acid into the cold silicate solution, 12·7 c.c. only being required. When boiled, the colour returned, but was dispelled when 13·5 c.c. had been added. These results are considerably below the truth.

TABLE VIII.

Results obtained in the titration of silicate of sodium ($Na_2Si_4O_9$).

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2O found.
Litmus, ...	15·05	·466
Methyl orange, ...	15·1	·468
Phenacetolin, ...	15·0	·464
Phenolphthaleïn (cold), . .	12·7	·393
Do. (boiled), . .	13·5	·418

XII.—Effect of alumina.

Soluble alumina, like silica, is seldom or never absent from caustic soda or potash. The experiments were made with an excessive quantity of alumina, the proportion used being equal to about 8 per cent. in an average strength caustic soda. A quantity of pure hydrate of aluminium, equal to ·515 gram. Al_2O_3, was prepared from alum by precipitation with ammonia. This precipitate was redissolved, reprecipitated, washed thoroughly, dissolved in 125 c.c. of normal caustic soda, and made up to 250 c.c. with water. 50 c.c. of this was employed for each test, and contained ·775 gram. of soda, and ·103 gram. of alumina.

Litmus.—When litmus is used 25·25 c.c. of the normal acid were consumed, in place of 25 required when no alumina was present, nor did the end-reaction come out very distinctly.

Methyl orange.—After a little more than 25 c.c. of the acid had been consumed, the alumina was all precipitated, and then gradually dissolved, the pink colour at first produced being quickly dispelled as the acid combined with the alumina. A decided and permanent change occurred when 30·7 c.c. had been added. This gives ·951 gram. of soda, as against ·775 really present, and if the difference be calculated to alumina it shows ·097 gram. of the latter compound instead of ·103. It is thus evident that nearly the whole of the alumina has been estimated along with the soda.

With *phenacetolin* and *phenolphthaleïn*, the real amount of soda used was obtained. The only effect of the precipitated alumina is to obscure the end-reaction slightly.

TABLE IX.

Results obtained in the titration of aluminate of soda.

Na_2O used for each test, ...	·775 gram.
Al_2O_3 ,, ,, ...	·103 ,,
$=Na_2O$,, ,, ...	·186 ,,

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2O found.
Litmus, ...	25·25	·782
Methyl orange, ...	30·7	·951
Phenacetolin, ...	25·05	·776
Phenolphthaleïn, ...	25·0	·775

XIII.—Effect of nitrite of sodium and potassium.

A solution of nitrite of potassium was prepared by decomposing with chloride of potassium a known weight of nitrite of silver, which was precipitated from a solution of nitrite of sodium. 20 c.c. of this nitrite of potassium liquor contained 1·7 gram. of KNO_2, and this quantity, diluted to 100 c.c., was employed for each test. The nitrite was found to be quite neutral to litmus, phenacetolin, and phenolphthaleïn. With methyl orange, however, the pink colour was not produced even after adding 30 c.c. of normal acid, but seemed to be destroyed at once by the liberated nitrous acid. Another quantity, containing ·085 gram. of the nitrite in the 100 c.c., gave a pink colour, with ·2 c.c. of acid, but this was slowly dispelled on standing a few minutes, leaving a pale yellow colour. Nitrite of sodium acts in the same way towards the indicators as nitrite of potassium. Nitrites are sometimes found in small proportion in caustic soda and potash.

XIV.—Determination of soda in borax.

The solution of borax employed contained 1·683 gram. of pyroborate of sodium in 50 c.c., the quantity used for each test.

With *litmus*, the blue colour began to purple when 13 c.c. had been added, but the change was not complete until 16·65 in the one case, and 16·6 c.c. of normal acid in the other, had been consumed. This shows ·516 and ·514 gram. of soda, as against ·516 really present. The end-reaction, however, is very indistinct.

Methyl orange is by far the best indicator for the estimation of soda in borax, and is indeed perfect in that respect. The change in colour at the end of the experiment was very sharply defined. The results agreed closely with those of litmus.

Phenacetolin.—Like litmus, the colour of this indicator slowly changes, and a good end-reaction is therefore impossible. The whole of the soda can be estimated by it.

Phenolphthaleïn is utterly useless for the purpose under consideration. The red colour disappears before half of the soda is determined in cold solutions. When boiled, a much higher result is obtained, but still very far below the truth.

TABLE X.

Determination of soda in borax.

$Na_2B_4O_7$ used for each test, ... 1·683
$=Na_2O$,, ,, ... ·516

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2O obtained.
Litmus, ...	16·65 — 16·6	·516 — ·514
Methyl orange, ...	16·7 — 16·65	·518 — ·516
Phenacetolin, ...	16·7 — 16·6	·518 — ·514
Phenophthaleïn (cold), ...	7·6 — 7·8	·235 — ·242
Do. (boiled), ...	11·0 — 11·3	·341 — ·350

XV.—Determination of free sulphuric, nitric, and hydrochloric acids.

It is quite plain from the results obtained when testing the behaviour of the sulphates, chlorides, and nitrates of the alkalies with the indicators under consideration, that these acids can be determined by a standard caustic alkali, excepting that ammonia cannot be used with phenolphthaleïn. Carbonate of sodium can be used in the cold if methyl orange is employed, and in the case of phenacetolin the caustic potash or soda should contain a little carbonate of potassium or sodium, so that the carbonate or bicarbonate will be formed when the end-reaction is reached, and the dark pink colour will be produced.

XVI.—Determination of free oxalic acid.

A normal solution of pure oxalic acid was prepared, and 20 c.c. of this was employed for each test.

With *litmus* the end-reaction was very well defined, and exactly 20 c.c. of normal hydrate of sodium were consumed, thus giving exactly the amount of oxalic acid.

Methyl orange.—It has been pointed out by Lunge that methyl orange must not be employed when oxalic acid is titrated, and from the following test it is evident that it cannot be relied on. When 12 c.c. of the normal alkali were added the pink colour

began to fade away, and was completely destroyed after the addition of 18 c.c.

Phenacetolin.—The addition of 19·8 c.c. produced a very faint pink colour, which was not fully developed till 20 c.c. had been consumed. This indicator cannot, therefore, be recommended as useful for the titration of oxalic acid.

Phenolphthaleïn, on the contrary, works admirably, the end-reaction being as delicate as with the mineral acids. The result agreed with that of litmus.

TABLE XI.

Determination of oxalic acid.

$H_2C_2O_4$ used for each test, ... ·900 grams.

Name of Indicator.	C.C. of Normal NaHO consumed.	Gram. $H_2C_2O_4$ found.
Litmus, ...	20·0	·900
Methyl orange, . . .	18·0	·810
Phenacetolin, . . .	19·8	·891
Phenolphthaleïn, . . .	20·0	·900

XVII.—Determination of acetic acid.

The sample of acetic acid in which the free acid was determined showed a specific gravity of 1·0472 at 15° C, which is equal to, according to Oudemann's table, 35·02 per cent. of $HC_2H_3O_2$. 100 grams. of this acid were made up to one litre with water, and 50 c.c. used for each titration, the caustic alkali used being standardized with normal sulphuric acid.

Litmus.—On adding the normal caustic soda, the red colour remained intact, but towards the end of the experiment became purple and almost blue before the end-reaction was accomplished. The last change in colour could only be observed by comparison with a blue litmus solution of the same strength as the liquid operated upon. 29·15 c.c. were consumed both with this experiment and with one tested with litmus paper, 1·749 gram. of acetic acid being obtained in each case.

Methyl orange is totally useless as an indicator in the estimation of acetic acid, only 3·5 c.c. of the alkali being consumed.

Phenacetolin.—The addition of 28 c.c. produced a pale rose colour, but the change was very undecided. This indicator is not adapted for this purpose.

Phenolphthaleïn is well fitted for use in the estimation of free acetic acid by caustic soda, as acetate of sodium is perfectly neutral to it, while that salt is alkaline to litmus. Several tests gave 29·2 c.c. of normal alkali consumed—these results being slightly, but quite distinctly higher than those obtained with litmus. The end-reaction is as delicate and sharply defined as in the determination of the mineral acids. If the solution in which the acetic acid is to be determined is dark coloured (as in some vinegars), it may be highly diluted, as dilution has little or no effect on the delicacy of phenolphthaleïn.

TABLE XII.

Determination of acetic acid.

Name of Indicator.	C.C. of Normal NaHo consumed.	Grams. of $HC_2H_3O_2$ found.
Litmus, ...	29·15—29·15	1·749—1·749
Methyl orange, . . .	3·5	·210
Phenacetolin, . . .	27·8	1·668
Phenolphaleïn, . . .	29·2—29·2	1·752—1·752

XVIII.—Determination of tartaric acid.

1·5 grams. of pure and dry tartaric acid were used for each experiment. The solution tested with *litmus* as indicator began to get purple after the addition of 19 c.c. of normal caustic soda, but the change to blue was not complete till 20 c.c. had been consumed, the tartaric acid found being exactly equivalent to the quantity taken. As with oxalic and acetic acids, *methyl orange* gives very low results, 16 c.c. only being required to dispel the pink colour. The tartaric acid found by *phenacetolin*, was slightly, but perceptibly, under the truth.

Phenolphthaleïn in this case, as with acetic acid, is the only perfect indicator among these four. Although the results obtained are much the same as those with litmus, the unimpaired delicacy

of the end-reaction gives phenolphthaleïn a great advantage over the former indicator.

TABLE XIII.

Determination of tartaric acid $H_2C_4H_4O_6$ used for each test, 1·5 gram.

Name of Indicator.	C.C. of Normal NaHo consumed.	Gram. of $H_2C_4H_4O_6$ found.
Litmus, ...	20—20	1·500—1·500
Methyl orange, . . .	16	1·200
Phenacetolin, ...	19·85	1·488
Phenolphthaleïn, . . .	20—20	1·500—1·500

XIX.—Determination of citric acid.

The sample used for the following tests was found to be free from impurity; but, as the water of crystallization varies to some extent, it was determined by drying for about 12 hours between 50° and 60° C., and then gradually raising the temperature to 100°. 8·53 per cent. was obtained, which is slightly lower than the theoretical proportion, 8·57 per cent. As 14 grams. were made up to 200 c.c., 20 c.c. contained 1·2806 gram. of dry citric acid ($H_3C_6H_5O_7$), this being the quantity operated upon. The normal caustic soda was standardized by normal sulphuric acid.

Litmus seems still to be considered the best indicator for the estimation of free citric acid, but it is a very defective one. In the first place, it gives a very indefinite end-reaction, and, in the second, the normal citrate of soda formed during titration is so alkaline as to preclude the use of sulphuric or any other mineral acid in the standardizing of the caustic soda. Pure citric acid must in that case be employed as the standard, and this entails the testing for impurities, and the tedious estimation of water described above. Allen, in his *Commercial Organic Analysis*, vol. i., p. 263, noticing these points, observes that neither logwood nor cochineal give sharp end-reactions, and recommends the use of carefully prepared litmus paper. In the two tests I made both litmus solution and paper were used, the last change in colour of the former being observed by placing it side by side with a litmus solution of equal strength, to which a little alkali had been added.

The results were identical, 19·7 c.c. of the normal alkali being consumed in each case. This shows ·02 gram. too little of citric acid, and is to be attributed to the alkalinity of the citrate, as sulphuric acid was made use of in testing the standard caustic soda.

Methyl orange and *phenacetolin* were found to be of no value in the titration of citric acid, 9 c.c. being consumed with the former and 17 with the latter.

Phenolphthaleïn.—This indicator is again distinguished from the others by its great delicacy in the determination of free citric acid, as it is in that of tartaric and acetic acids. Several tests were made, and in every case 20 c.c. of the normal acid were consumed, giving results extremely close to the real amount of citric acid present. Phenolphthaleïn has thus two advantages over litmus for the determination of citric, tartaric, and acetic acids; first, it gives a sharply defined end-reaction, and, second, sulphuric acid can be employed in standardizing the caustic soda.

TABLE XIV.

Determination of citric acid, sulphuric acid being used for the standardizing of the normal caustic soda.

$H_3C_6H_5O_7$ used for each test, ... 1·2806 gram.

Name of Indicator.	C.C. of Normal NaHO consumed.	Gram. of $H_3C_6H_5O_7$ found.
Litmus, ...	19·7—19·7	1·2608—1·2608
Methyl orange, . . .	9·0	·5760
Phenacetolin, . . .	17·0	1·1000
Phenolphthaleïn, . . .	20·0—20·0	1·2800—1·2800

Litmus and *phenolphthaleïn* were further tested with a sample of lime juice, in order to make certain that a similar difference in result would be brought out when these indicators were applied to the determination of citric acid in this substance. Of course the other free acids existing in the juice would be included in the result. 10 c.c. of the sample, measured at 15·5° C., were employed.

Litmus paper was used as indicator, as the yellow colouring matter of the lime juice darkens so much as to make litmus

solution useless. 13·0 and 13·05 c.c. of normal alkali were consumed, which give 36·5 grains of dry citric acid per ounce, 30 grains per ounce being the Board of Trade standard.

Phenolphthaleïn.—With this indicator the most convenient quantity to use is 10 c.c. of the juice, diluted to 150 or 200 c.c. As the yellow colouring matter becomes darker towards the end of the experiment, the end-reaction is not quite so delicate as in a colourless solution, but can still be recognized without the least difficulty. 13·25 c.c. of the normal alkali were consumed in each case—these results being equal to 37·1 grains of dry citric acid per ounce.

TABLE XV.

Determination of free acids in lime juice.

10 c.c. of sample used for each test.

Name of Indicator.	C.C. of Normal NaHO consumed.	Grains of $H_3C_6H_5O_7$ per ounce.
Litmus, ...	13·0—13·05	36·40—36·54
Phenolphthaleïn, . . .	13·25—13·25	37·10—37·10

IX.—*Approximative Photometric Measurements of Sun, Moon, Cloudy Sky, and Electric and other Artificial Lights.* By Sir William Thomson, F.R.S., &c.

[Read before the Society, 29th November, 1882.]

Sir William Thomson pointed out that the light and heat perceived in the radiations from hot bodies were but the different modes in which the energy of vibration induced by the heat was conveyed to our consciousness. A hot kettle, red-hot iron, incandescent iron, platinum, or carbon, the incandescence in the electric arc, all radiate energy in the same manner, and according as it is perceived through the sense of sight, by its organ the eye, or by the sense of heat,* we speak of it as light or heat. When the

* Sometimes wrongly called the sense of touch. The true list of the senses, first given, I believe, by Dr. Thos. Reid (born 1710, and Professor of Moral Philosophy in the University of Glasgow from 1764 to 1780), makes two of what used to be called the sense of touch, so that, instead of the still too common wrong-reckoning of five senses, we have six, as follows:—

Sense of Force.	Sense of Light.
,, Heat.	,, Taste.
,, Sound.	,, Smell.

The sense of force is the department left to the sense of touch, when the sense of heat or of temperature is taken from it. The sense of touch, other than temperature, has sometimes been, not very judiciously or logically, called "Tactile sense," those who have so called it not having noticed that "tactile" is merely the adjective of or belonging to touch. Physiologists have justly objected to the name "muscular sense of touch," by which, I believe, Thomas Reid himself, and certainly some of his successors in Glasgow, who, teaching his philosophy in this matter, have designated the sense of touch other than temperature. The perception of roughness, as distinguished from smoothness (when we touch a piece of sandstone or of loaf sugar, and compare the sensation with what we perceive when we touch a piece of glass), would not be regarded by physiologists as a muscular perception. But it is a sense of force and places of application of force which, in the case of touching a rough body, are the little areas of greater pressure distributed among places of less pressure or of no pressure.

period of vibration is longer than one four-hundred-million-millionth of a second, the radiation can only be perceived by the sense of heat; when the period of vibration is shorter than one four-hundred-million-millionth of a second, and longer than one eight-hundred-million-millionth of a second, the radiation is perceived as light, by the eye.

Pouillet, from a series of experiments, deduced a value of the energy radiated by the sun, equal, in British units, to about 86 foot-pounds per second per square foot of the earth's surface,* or about 1 horse-power to every $6\frac{1}{2}$ square feet at the earth's surface. We may estimate from this the value of the solar radiation at the surface of the sun. The sun is merely an incandescent molten mass losing heat by radiation, and surrounded by an atmosphere of incandescent vapour, so that the radiant energy really comes out from any square foot or square mile of the sun's surface, as from a pit of luminous fluid which we cannot distinguish as either gaseous or liquid. Take, however, instead of the sun, an ideal radiating surface of a solid globe of 440,000 miles radius. The distance of the earth being taken as 93 million miles, the radius of the sun is equal to, say in round numbers, one two-hundredth of the earth's distance; hence the area at the earth's distance corresponding to one square foot of the sun's surface, is equal to 40,000 square feet. The radiation on this surface is (40,000 × 86, or) 3,440,000 foot-pounds, which is therefore the amount of radiation from each square foot of the sun's surface. This amounts

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When we perceive resistance to our two hands pressing on solid matter, or holding up weights, we perceive force and places of application of force; the places of application of the force being the surfaces of the two hands. In respect to this case of the perception of force, physiologists would no doubt accept Thomas Reid's name of "muscular sense." But whether the person perceiving the force is conscious of a sensation in the muscles of his arms, or, as in the case of perceiving roughness, is merely conscious of a sensation in the sensitive material of his fingers, or is conscious of roughness in the tips of his fingers, and of muscular stress in the muscles of his fingers, the thing perceived is still force and places of application of force. The simplest proper name of the sense to which these perceptions belong is the sense of "force."

* More recent observers have found larger and larger results. Langley (*Comptes Rendus*, 11th Sept., 1882, and *American Journal of Science*, vol. xxv., March, 1883) finds 1·7 times the value given by Pouillet, and quotes MM. Soret, and Crova and Violle, who found respectively 1·3 and 1·5 times Pouillet's result.

to about 7,000 horse-power, which, according to our brain-wasting British measure, we must divide by 144, if we wish to know the radiation per square inch of the sun's surface, which we thus find to be 50 horse-power.

The normal current through a Swan lamp giving a 20-candle light is equal to 1·4 amperes with a potential of 40 to 45 volts. Hence the activity of the electric working in the filament is 61·6 ampere-volts or watts (according to Dr. Siemens' happy designation of the name of Watt, to represent the unit of activity constituted by the ampere-volt). To reduce this to horse-power we must divide by 746, and we thus find about 1-12th of a horse-power for the electric activity in a Swan lamp. The filament is 3½ inches long, and ·01 of an inch in diameter of circular section; the area of the surface is thus 1-9th of a square inch, and therefore the activity is at the rate of 3-4ths of a horse-power per square inch. Hence the activity of the sun's radiation is about sixty-seven times greater than that of a Swan lamp per equal area, when incandesced to 240 candles per horse-power.

In this country the standard light to which photometric measurements are referred is that obtained from what is known as a "standard candle." Latterly, however, objections have been raised against its accuracy. It has been said that differences of as much as 14 per cent. have been found in the intensity of the light given by different standard candles, and that serious differences have been observed, in the intensity of the light from different parts of the same candle, in the course of its burning. The Carcel lamp, the standard in use in France, has been regarded as the only reliable standard. It is, no doubt, very reliable and accurate in its indications; but it should be remembered that its accuracy is greatly owing to the careful method and the laborious precautions taken to secure accuracy. If something akin to the precautions applied to the Carcel lamp by Regnault and Dumas were applied to the production and use of the standard candle, there is little doubt but that sufficient accuracy for most practical purposes could also be obtained with it; probably as good results as are already obtained by the use of the Carcel lamp.

At the Conference on Electrical Units which met in Paris lately, a suggestion was made to use as a standard for photometric measurements the incandescence of melting platinum, and very interesting results and methods in connection with the

proposal were presented to the meeting. According to experiments by Mr. Violle, which M. Dumas reported to the Conference, a square centimetre of liquid platinum at the melting temperature gives of yellow light seven, and of violet light twelve times the quantities of the same colours given by a Carcel lamp. The apparent area of the Swan filament, being one-ninth of a square inch, is ·23 of a square centimetre, and when incandesced to 20 candles must be about as bright as the melting platinum of Mr. Violle's experiment, as the 7 carcels of yellow and 12 of violet must correspond to something like 10 carcels or 85 candles, in the ordinary estimation of illumination by our eyes. The tint of Mr. Violle's glowing platinum cannot be very different from that of the ordinary Swan lamp incandesced to its "20 candles." Thus, both as to tint and brightness, it appears that melted platinum at its freezing temperature is nearly the same as a carbon filament in vacuum incandesced to 240 candles per horse-power.

For approximative photometric measurements the most convenient method is certainly that of Rumford, by a comparison of the shadows cast by the sources of light on a white surface. The apparatus necessary are only a piece of white paper, a small cylindrical body such as a pencil, and a means of measuring distances. Ordinary healthy eyes are usually quite consistent in estimating the strength of shadows, even when the shadows examined are of different colours, and with a reasonable amount of care photometric measurements by this method may be obtained within 2 or 3 per cent. of accuracy. The difference in the colours of the shadows is, of course, due to each shadow being illuminated by the other light.

Arago has compared the luminous intensity of the sun with that of a candle, and estimates it as equal to about 15,000 times that of a candle flame.

Seidel, as Sir W. Thomson had been informed by Helmholtz, estimated the luminous intensity of the moon as about equal to that of grayish basalt or sandstone. An experiment on sunlight made in Glasgow on the 8th of this month (since this paper was read), compared with an observation on moonlight, which he made at York during the meeting of the British Association there in 1881, had led him to conclude that the surface of the moon radiates something not enormously different from one-quarter of the light incident upon it. It would be exactly this, if the transparency of the Glasgow noon atmosphere of December 8, 1882, had been

exactly equal to that of the York midnight atmosphere of September, 1881, referred to below, for the respective altitudes of the sun and moon on the two occasions. The observation on moonlight referred to above showed the moonlight at the time and place of the observation (at York early in September, 1881, about midnight, near the time of full moon) to be equal to that of a candle at a distance of 230 centimetres. The moon's distance ($3{\cdot}8 \times 10^{10}$ cm.) is $1{\cdot}65 \times 10^{8}$ times the distance of the candle. Hence, ignoring for a moment the loss of moonlight in transmission through the earth's atmosphere, we find $(1{\cdot}65 \times 10^{8})^{2}$, or twenty-seven thousand million million as the number of candles that must be spread over the moon's earthward hemisphere painted black, to send us as much light as we receive from her. Probably about one and a half times as many candles, or say forty thousand million million would be required, because the absorption by the earth's atmosphere may have stopped about one-third of the light from reaching the place where the observation was made. The moon's diameter is $3{\cdot}5 \times 10^{8}$ centimetres, and therefore half the area of her surface is 19×10^{16} square centimetres, which is nearly five times forty thousand million million. Thus it appears that if the hemisphere of the moon facing the earth were painted black and covered with candles standing packed in square order touching one another (being say one candle to every five square centimetres of surface), all burning normally, the light received at the earth would be about the same in quantity, as estimated by our eyes, as it really is. It would have very much the same tint and general appearance as an ordinary theatrical moon, except that it would be brightest at the rim and continuously less bright from the rim to the centre of the circle where the brightness would be least.

The luminous intensity of a cloudy sky he found about 10 a.m. one day in York during the meeting of the British Association to be such that light from it through an aperture of one square inch area was equal to about one candle. The colour of its shadow compared with that from a candle was as deep buff yellow to azure blue—the former shadow being illuminated by the candle alone, the latter by the light coming through the inch hole in the window shutter.

The experiment on sunlight of last Friday (December 8) showed, at one o'clock on that day, the sunlight reaching his house in the University to be of such brilliancy that the amount of it coming through a pin-hole in a piece of paper of ·09 of a centimetre

diameter, produced an illumination equal to that of 126 candles. This is 6·3 times the 20-candle Swan light, of which the apparent area of incandescent surface is ·23 of a square centimetre, or 3·8 times the area of the pin-hole. Hence the sun's surface, as seen through the atmosphere at the time and place of observation, was 24 times as bright as the Swan carbon when incandesced to 240 candles per horse-power. By cutting a piece of paper of such shape and size as just to eclipse the flame of the candle, and measuring the area of the piece of paper, he found about 2·7 square centimetres as the corresponding area of the flame. This is 420 times the area of the pin-hole, and therefore the intensity of the light from the sun's disc was equal to (126×420) about 53,000 times that of a candle-flame. This is more than three times the value found by Arago for the intensity of the light from the sun's disc as compared with that from a candle-flame—so much for a Glasgow December sun!

The ·09 cm. diameter of the pin-hole, of the Glasgow observation, subtends, at 230 centimetres distance, an angle of 1/2556 of a radian, which is 23·7 times the sun's diameter (1/108 of a radian). But at 230 cm. distance the sunlight through the pin-hole amounted to 126 times the York moonlight (which was one candle at 230 cms. distance). Hence the Glasgow sunlight was $[(23{\cdot}7)^2 \times 126$ times or] 71,000 times the York moonlight. We cannot, therefore, be *very far* wrong in estimating the light of full moon as about one-seventy-thousandth of the sunlight, anywhere on the earth. This, however, is a comparison which, because of the probably close agreement of the tints of the two lights, can probably be made with minute accuracy; and we must, therefore, not be satisfied with so very rough an approximation to the ratio as this 71,000. A lime light, or magnesium light, or electric arc-light, carefully made and remade with very exactly equal brilliance, for each separate observation of sunlight and moonlight might be used for intermediary.

X.—*On the Preservation of Food by Cold.* By J. J. COLEMAN, F.I.C., F.C.S.

[Read before the Society, 17th January, 1883.]

SCARCELY three-and-a-half years have elapsed since I went out to New York with the first cold-air machine constructed under my superintendence, the building and erecting of which had occupied myself and partners, Messrs. Bell, for several months. No inventor, previous to this, had succeeded in making mechanical refrigeration trustworthy for the preservation of food during long sea voyages, or, in fact, had felt sufficient confidence to push the matter at all with shipowners.

Steamers and sailing vessels fitted up with machinery on the lines we laid down in 1878 are now to be found regularly traversing the Atlantic and Pacific, and frequenting the ports of London, Glasgow, Melbourne, Sydney, Canterbury, Otago, Java, Calcutta, New York, Bermuda, and crossing the Red Sea, the Indian Ocean, or the Mediterranean. Their aggregate cooling power is such that they could without difficulty freeze 200,000 tons per annum, and, if worked at full power and speed, their steam cylinders would indicate full 4,000 horse-power. Their work is various. They have brought frozen salmon from the shores of Labrador and delivered it in London; they have kept it in the frozen state in London for six months whilst being sold in instalments; they have again transferred it to the shores of Australia, where it has finally appeared perfectly fresh and in splendid condition on the tables of the merchant princes of Melbourne and Sydney. They have conveyed a great number of tons of English fish by means of the Orient steamers to the same colonies, comprising soles, turbots, whiting, etc., which have been bought up and eaten by our Australian cousins, curious to taste and eager to pay several shillings a pound for such dainties. They have conveyed frozen salmon from the managers of the Peninsular and Oriental Co.

to the table of the Khedive of Egypt; and the ships of the same company, fitted up with these machines, provide luxuries for their passengers never previously thought of.

But it is chiefly in providing for the meat supply of this country that these machines have had such a rapid development.

The history of their conception and the relationship of the labours of myself and partners to the inventions of previous date, together with scientific questions involved in their construction, have been treated at length in a paper, prepared at the request of the Institution of Civil Engineers in London, and which was read at the meeting of 14th February, 1882, and discussed at a meeting held on February 21st, presided over by Sir W. Armstrong.

Competing machine makers were present, but it did not appear that anything suggested were more effective than the machines designed by the author. A copy of this paper, for which the Institution have done me the honour to award a Watt Medal and Telford premium, can be seen in the library of our Society; but there are many points of interest connected with the subject not touched upon in that paper, and much has been done in the year which has elapsed since it was read which make me think that it will not be uninteresting to lay the matter before you.

When submitting my paper to the Institution of Civil Engineers, I employed a number of diagrams—as many as possible of which are hung on the walls of this room to-night—and as the lettering of the various parts is uniform, a cursory inspection will enable them to be understood after describing the first, which shall be that of the small machine on board the s.s. *Servia* of the Cunard line used for cooling the ship's provisions. There is not so much special necessity for the use of these machines for cooling ship's provisions on the Atlantic traffic as upon the Oriental or West India traffic, and therefore not much power required, and *that* principally in the summer months; but this machine affords a convenient illustration of the principles upon which they are constructed. The motive power of the machine is the steam-engine cylinder, A, the piston rod of which has got attached to its extremity a piston air-pump, P, and by means of which atmospheric air is sucked in and compressed or condensed to a small bulk, say one-fourth or one-third of its original bulk. In this process the air becomes very hot, because the work employed in compression reappears as heat, which is communicated to the air. Before anything further can be done with the air this heat requires to be removed, for which purpose

not only is a little water being constantly injected into the air-compressor, but the air is made to ascend a small tower, at the top of which there is a rose, through which the water injection pump forces water in the form of rain. The surplus water descends and drains off by a trap controlled by a ball-cock, which allows the water to pass but retains the air. The compressed air—say of 50 or 60 lbs. pressure to the inch—by this time should be about as cool as the water, which, at sea, is, of course, the sea water, and on land is, of course, river water or spring water, so that up to now no real cooling has been done. All that has been accomplished is to remove the heat *created by the operations* which have brought the air into a compressed state.

The air requires now to be thoroughly dried before proceeding to expand it, and for this purpose it is conveyed through the horizontal pipes, R, surrounded on their outside by the cool air of the room being refrigerated. This brings the compressed air a few degrees below that of the water, and is merely for the purpose of liquefying and removing the vapour existing in the air previous to the expansion, which operation is the real source of cold.

If the compressed air is expanded back to its original atmospheric pressure by allowing it to blow through a small pipe or hole, it is not permanently cooled at all, but if it is expanded behind a working piston, so as to get work out of it like getting work out of steam, then the air becomes cooled as much as 50, 100, or 200 degrees below freezing point, according to the amount of previous compression. Accordingly, in this *Servia* machine the compressed air is conveyed from the moisture-depositing pipes, R, and is expanded in the act of doing work in the expansion cylinder, E. It then becomes cooled considerably below zero, and is conveyed in a constant stream amongst the beef and other provisions in the chamber containing the passengers' food. That the performance of work by the expanding of the air is necessary to the production of cold, is one of the first principles of the mechanical theory of heat discovered by Dr. Joule, and experimented on by this great man and Sir William Thomson conjointly, more than thirty years ago; and in the case of the Bell-Coleman machines the work done by the expanding air is employed in reducing the amount of steam power which would otherwise be required to drive the machine. It was, however, very interesting to me to demonstrate the thing on the large scale, which I did in the case of this very machine by the following experiment:—Instead of allowing the air, as usual,

to expand in the act of working the piston in the expansion cylinder, E, I took the piston out, so that the expanding air could go through the cylinder without doing work into the blast box, D, and it was found that, when the air-pressure was regulated by the throttle-valve, V, no lowering of the temperature of the air of the blast-box could be detected, when, at exactly similar air-pressures, but with the expansion taking place in the act of doing the work of propelling the piston, fully 60 degrees reduction of temperature occurred. The air pressure at which the experiment could be made was less than the normal working pressure of the machine, owing to the crank shaft being deprived of the assistance of the expansion cylinder.

It will be interesting to remind you that Sir William Thomson, who was great in thermo-dynamics as he has since been in electrical science, read a paper to this very Society so far back as 1852, in which he described the principles upon which cold-air machines should be constructed, and it has been a source of great gratification to him that the engineering of the matter has turned out so successfully.

Many attempts were made by engineers to construct cold-air machines, between the reading of Sir Wm. Thomson's paper and the construction of the first Bell-Coleman machine in 1879, but they were all baffled by matters of detail, more especially in regard to the presence of aqueous vapour in atmospheric air, the dealing with which has been the subject of the inventions which bear my name and those of my partners.

The principles which are involved in the *practical* construction of these machines were summarised by me in my paper to the Institution of Engineers as follows:—

1. That atmospheric air is really a mixture of aqueous vapour and air, and that when such mixture is compressed into pipes surrounded externally by water of the same temperature as the air before compression, the invisible vapour of the air becomes condensed in the direct ratio of the compression, in virtue of the law of physics demonstrated by Dalton, and expressed by the statement that a cubic foot of air in contact with water contains exactly the same weight of vapour, whatever may be the density of the air. If the density is increased, the vapour liquefies—if it is diminished, water evaporates into the air.

2. Compressed atmospheric air of usual humidity is not therefore made wetter by injection of water, provided the surplus water is

run off continuously by automatic traps, air being actually dried by compressing it in contact with water, removing the water and expanding it.

3. Direct injection is the quickest and most effective method of cooling air to the temperature of the water, which is a condition necessary to the working of a machine with the least expenditure of power.

4. Injection of a shower of water into freshly-compressed air tends to settle the fog caused by the sudden condensation of the invisible atmospheric vapour, thus facilitating its removal by traps.

5. That whilst the direct injection of water is desirable for cooling the air to the temperature of the water, it is not absolutely essential, if the compressed air be passed through a sufficient number of pipes surrounded by cooling water, the ultimate result in either case being that the compressed air can only be reduced to the temperature of the water, which is not sufficient to liquefy the vapour usually contained in the air, except the air pressures employed be excessively high—which is fatal, according to the first principles of thermo-dynamics, for working a machine economically.

6. That every lb. of vapour unnecessarily condensed liberates as much heat as will raise about four thousand times its weight of air 1° Fahrenheit, and that air absolutely dry is a condition that would abstract the fluids of animal tissue, and indeed is a phenomenon unknown in nature, the degree of humidity being generally over 50°, even in what is, in common parlance, called "dry air."

7. That a convenient way of liquefying such vapour is to apply a portion of the cold air produced by the machine to the external surface of the pipes or other vessels conveying the compressed air already cooled by water to the cylinder in which it is to be expanded, the liquid condensed in this way being removed by automatic traps.

Still dealing with machines intended for ships' provisions, I will direct your attention to Fig. 4, which represents in plan and elevation a machine which was exhibited at the Naval Exhibition in full working order last May, and which pattern has been adopted for the largest steamship afloat, the *City of Rome*, and for the new steamer, *Normandie*, of the Compagnie Transatlantique Générale of Havre.

The air is compressed in the air-pump, P, deprived of its heat by compression in the tower, T, passes through the horizontal moisture-depositing pipes packed in the sole-plate, and is finally expanded in the act of doing work in the cylinder, E, from whence it is conveyed round the outside of the metallic cells containing the water required to be frozen for table use, and then is delivered into the chamber containing the meat and provisions. The length of this machine is 12 feet, its breadth at the point P is 3 feet, and at the point E is 4 feet, and its height is such that it will go 'tween decks of any vessel. Its best position is adjoining the main engine-room, but as the stewards' departments are frequently elsewhere, the machine is sometimes placed on the upper deck, or in the position usually occupied by the old ice-house. The air delivered by these machines is so dry, as well as cold, that calico or paper hung up in it ignites readily on application of a flame, so that the provisions are prevented from getting into the slimy condition which they assume when packed in ice. The provision-room of a large steamship measures internally perhaps 2,000 cubic feet, including the space necessary for storing the wines, salt meat tanks, etc. This pattern of machine is proving a very useful one in another direction, for, by arrangement with Messrs. Crossley Bros., the makers of the Otto gas engines, they are being constructed to be driven by gas instead of by steam. The air-pump in this new machine is placed in the position of steam cylinder, Fig. 4, and the gas motor cylinder takes the place of the air-pump, P, on same diagram. Such machines affording a cooling power equal to what could be obtained by the use of half a ton or a ton of ice per day, are now being made for retail shops, country mansions, etc.

Turning now to diagram 3 you have the favourite type of machine for doing work on a large scale. In this case there are two air-compressors, one being attached to piston-rod of steam cylinder and the other to piston-rod of expansion cylinder. A large number of these machines have been constructed as follows:—Each air-pump is 16 inches diameter and 2 feet stroke; the steam cylinder is 18 inches diameter and 2 feet stroke; and the expansion cylinder 17 inches diameter and 2 feet stroke.

Such machines are large enough to carry 600 cattle divided into quarters, and to keep the same within two degrees of the freezing-point of meat, in the Atlantic traffic. Both machine and cattle can be packed in the 'tween decks of a steamer of say 100 feet

long, 40 feet wide, and 6 feet high, of which the machine will occupy 7½ per cent. Cargoes of this kind arrive in Glasgow every week.

Still larger machines have been used for the bringing of frozen meat from Australia and New Zealand, and in which the compressors measure 21 inches diameter and 2 feet stroke.

On diagram 5 is a section of one of Messrs. Patrick Henderson & Co.'s ships fitted up, the end view of the engine appearing in top left hand corner, and the space cooled being not only the 'tween decks, but the lower hold of the forward half of the vessel.

This vessel is a sailing vessel, called the *Dunedin*, which recently brought 175 tons of mutton from New Zealand, kept in a frozen state during the whole voyage of 98 days, the meat having been shipped by the New Zealand and Australian Land Co., Limited; and, in a book of information recently published by the able general manager of this company, W. S. Davidson, Esq., of Edinburgh, is to be found the following description of the shipment:—

The sheep were killed on the Company's Totaro estate, and were conveyed about sixty miles in ventilated railway vans, to the ship's side, where they were hung up on hooks in the refrigerating chamber until stiff with frost, after which they were put in calico bags and passed into the lower chamber, where a temperature of 10° below zero soon made them as hard as wood, and ready to be stowed away in layers as close as they could be packed. Loading commenced in January, 1882, and within a month the shipment of 4,909 carcases of sheep and 22 pigs were all safely stowed away, hard frozen. The *Dunedin* sailed from Port Chalmers on the 15th February, 1882, and arrived at the London Docks after a long passage of 98 days. Notwithstanding this, and the exceptionally hot weather encountered in the tropics, where the vessel was becalmed for a long time, the meat arrived in splendid condition, and within a fortnight the whole was disposed of at satisfactory prices.

The Smithfield salesmen were much surprised at the quality and condition of the sheep, and in fact every one who saw them admired them very much. As specimens of what the country is capable of, some 30 large sheep, weighing from 140 to 162 lbs. each, were sent. Not only was the experiment a thorough success from a scientific point of view, but it was also very satisfactory financially speaking.

Altogether they brought				£8,009	14 3
The charges were—					
Calico for bags, . .	£91	8	9		
Keeping meat frozen after arrival in the Docks, .	43	11	9		
Freight, ...	2,779	9	5		
Insurance, ...	414	13	9		
Other expenses of discharging, carriage to Smithfield, &c.,	463	18	8		
				3,793	2 4
				£4,216	11 11

Netting 3·23d. per lb. for the sheep.

Although many of the carcases had been frozen four months, they were bright and clean-looking as newly-killed mutton.

The vessel *Dunedin* has gone out again to New Zealand, together with a sister ship of the same line, called the *Lady Jocelyn*, fitted up with the same-sized machines, the quantity of meat to be increased to 250 tons or thereabouts for each vessel.

In the case of the steamships of the Orient Line and other steamers, the cold chambers for containing the meat have been constructed in the 'tween decks of the ship, so that their form varies; but the method of building them consists of lining the walls, the floor, and the roof of the meat-chamber with wood-work containing hollow spaces filled with wood, charcoal, or shavings. It is found that 7 inches thick of such lining forms very fair insulation; but, in the case of tropical ships, it is frequently made 10 or 12 inches thick. It is also found that the larger the quantity of meat brought over, the more economically can the work be done. Thus the prime cost of the machinery for carrying a pound of meat is 25 per cent. less when a ship is fitted up to carry 1,000 tons instead of 500 tons, and there is a further gain of 10 per cent. in the less packing space required.

A large-sized steamship, costing say £100,000, could have its entire cargo space refrigerated by machinery costing about £10,000, so that it may be safely assumed that any big ship could be adapted to carry a frozen instead of an ordinary cargo at an increase on the prime cost of 10 per cent. or 15 per cent.; and this is the proper way of looking at it, because the machinery is as solid and substantial as the vessel's engines.

The largest machine which I have been connected with is one constructed for land purposes, and which was sent out to Sydney some months ago, after being tried in the shops. Its erection is

now completed, and the diagram on the walls shows the nature of the building which it is employed in cooling, the floor area of which is 80 feet by 100 feet.

The floor of this room is constructed of concrete, upon which are bedded 3-inch planks by means of asphalt. The sides of this room are of masonry, but the inside is lined with several inches of thin boards, an air space of an inch or two being left between each layer of boards; the ceiling is covered a foot deep with sawdust, and over that the usual rafters of a double lean-to roof.

It has been designed for cooling the whole of the meat supply of Sydney to 40° in the height of summer, the air then being above blood heat, and prevents the stiffening of the meat we are accustomed to in this country called "Rigor mortis," and without which the meat decomposes in twelve hours.

The machinery supplied to do this work consisted of a pair of air-compressers of 24 inches diameter and 3 feet stroke, an expansion cylinder of 25½ inches diameter, and a steam cylinder of 27 inches diameter and 3 feet stroke, and the whole work has been done under the superintendence of the London consulting engineer of the colony, Mr. John Fowler, C.E., of Forth Bridge celebrity, and under the inspection in the colony of the Government engineer there. The official trial has lately taken place, when the machine run for thirty days, and it was found that the air discharged fresh from the machine registered as low as 105° below zero Fahr.—that is, its temperature was 137° below freezing point registered with an alcohol thermometer, as mercury itself freezes something like 40° below zero. This very low temperature is fully 50° below the lowest temperature that has ever been recorded by any navigator in the Arctic regions; but it is not the limit of these machines, as by increasing the working pressure of the air, or, in other words, the degree of compression of the air, which, with the Sydney machine, was 45 lbs. per square inch, still lower temperatures can be obtained.

The lowest temperatures which have been obtained in scientific laboratories has been about 200° below zero, but it is believed that before 460° below zero is reached, all known gaseous matters would be absolutely solid.

The fact of air being so excessively low in temperature when first liberated from the machine does not in any way interfere with keeping a regular temperature in the cold chambers—in fact a temperature so regular that nothing even in the most equable

climate can possibly be compared to it. An examination of thousands of recorded observations of the Bell-Coleman machines traversing the Atlantic show that the temperature of the chambers does not vary 3° during a voyage, being much less variation than the difference between the hours of morn and even of any ordinary winter day.

This even temperature is maintained by distributing the cold air by pipes carried along the top corners or roof of the chamber, and having outlets at regular intervals, the velocity or flow of the air being regulated by the speed at which the machine is worked. There is no big blast or current of air perceptible at these outlets, the cold air tranquilly displacing the warmer atmosphere as easily as cold winter air permeates through the chinks of windows and doors of a sitting or drawing room, and the atmosphere is no more disturbed than in such cases. It follows from this that a chamber can be kept at any temperature deemed desirable—thus, 20° Fahr. is thought a very desirable temperature for bringing meat long distances across the tropics, 28° Fahr. is thought desirable for bringing meat from America, and 40° Fahr. for preserving town meat in public abbatoirs; whereas in India the temperature required for sitting rooms is perhaps 70° or 80° Fahr. There is no difficulty in meeting any of these conditions; and, in regard to India, I give you a calculation I submitted to the Institution of Civil Engineers. As regards public buildings, hospitals, etc., experience has demonstrated that machines of sufficient power to cool 100,000 cubic feet of air per hour, through a range of 150°, can be worked with a steam cylinder indicating 100 to 150 h.p. by the consumption of one-fifth of a ton of coal an hour. The attendance upon such a machine would not cost more than 1s. 6d. per hour, the lubrication 6d., and the interest on capital, say, 1s. per hour, so that the whole 100,000 cubic feet of air could not cost more than, say, 8s. 4d.; but being so excessively cold, it could be mixed with 400,000 cubic feet of uncooled air, and this would then give a supply of air per hour to 1,000 people, at the rate of 500 cubic feet per head per hour, cooled 30° below the external atmosphere—a very excellent ventilation at the cost of one-tenth of a penny per head. Whilst on this subject of figures, it may be interesting to state that the cost of cooling the meat in the Sydney abbatoir has been calculated to be $\frac{1}{50}$th of a penny per lb. of meat cooled per day, allowing interest on money at 5 per cent. and depreciation at 5 per cent., and the working

expenses of the machine. And in further reference to this subject, Messrs. Hennicke & Goos, civil engineers of Hamburg, Germany, have recently published some figures relating to powerful Bell-Coleman machinery erected at the abbatoirs of Mr. Koopman, who supplies large quantities of breakfast bacon for the London markets.

To measure accurately the work being done by a cold-air machine it becomes necessary to take observations—1° of the horse-power being exerted by the steam cylinder, 2° of the temperature of the compressed air previous to expansion, 3° of its temperature immediately after expansion, 4° of the terminal pressure of the air of the expansion cylinder, as read off an indicator card. The calculation presupposes that the compressed air has been cooled to the temperature of the water available for cooling it, and it is then as follows:—First, to arrive at the weight of a cubic foot of air at the end of the stroke, let

W = weight of cubic foot of air in lbs. avoirdupois.
P = pressure of air in lbs. absolute per square inch as read off an indicator card taken of expansion cylinder.
T = the absolute temperature in degrees of Fahr. at the moment of discharge.

Then $$W = \frac{P \times 2{\cdot}704.}{T}$$

Having now ascertained the weight of a cubic foot of air, it merely remains to multiply it by the number of cubic feet swept out of the cylinder in a given time, say one hour, then by the specific heat of air, and the weight of water is arrived at which could be cooled through the same range as the air has been cooled. This can then be calculated as heat units.

The formula now becomes

$$w = \frac{W \times S \times R,}{L}$$ in which

W = weight of air discharged per hour.
S = specific heat of air (0·23).
R = range of cooling in degrees Fahr.
L = latent heat of ice.
w = lbs. ice at 32° produced from water at 32° per hour.

Returning, however, to oceanic food refrigeration, which is no doubt the most important application of refrigerating machinery that we are acquainted with, it seems abundantly clear that when once meat is frozen it will keep indefinitely, and when thawed it

is practically in the same state as at the moment before freezing—that is, if the thawing takes place in a dry atmosphere—otherwise the aqueous vapour contained in the warm air into which the meat is immersed for thawing precipitates upon the surface of the meat as moisture, just as dew precipitates upon grass or shrubs cooled by radiation into space during the night time.

There has been about 4,000 tons of Australian and New Zealand frozen meat delivered into Great Britain by means of cold air machines up to the present date.

On the authority of Sir Francis Dillon Bell, who read an interesting paper recently to the Royal Colonial Institute on the resources of the Australian Colonies, it is claimed that Australia and New Zealand could export to England 1,000 tons of meat daily, and maintain this *ad libitum*. This statement of Sir Francis is probably correct, when we bear in mind their extraordinary rapid rate of development.

It appears that the commerce of Australasia is now of the value of £100,000,000 annually, an amount equal to the whole commerce of the United Kingdom at the accession of Queen Victoria.

In these far-off countries they have spent £56,000,000 in railways, which are ready to bring some of the 65,000,000 sheep, or 8,000,000 of cattle, they possess to their splendid seaports. The question of making arrangements, however, for the importing into this country of such a quantity as 1,000 tons a-day is a very serious one.

As one ton dead weight of meat requires 120 cubic feet gross of space in a ship, the whole of the steamers that were built in the United Kingdom during the last 12 months would not be too much for carrying it, supposing they were all put upon the traffic. These steamers were 474 in number and 343,361 in tonnage; or, to put it in another way, supposing all the steamers of the Cunard, the Anchor, the Guion, the State, the Inman, the National, and the White Star Lines, which usually carry passengers to New York, were put on this trade, they couldn't bring over this quantity of meat, and there would be the very awkward question as to the kind of cargo they could carry on the outward voyage.

The metropolitan meat markets in London are said to get through about a thousand tons of meat per day, and the average consumption of meat per head in the United Kingdom is stated, in M'Culloch's "Commercial Dictionary," to be about 100 lbs. per head per annum, so that we may fairly conclude the total

consumption of meat in the United Kingdom is something between 3,000 and 5,000 tons per day.

On the other hand, according to the Board of Trade agricultural returns in the year 1874, we had 30,000,000 of sheep in the United Kingdom. They have now diminished to 24,000,000, and the amount of cattle has been stationary for some time, whilst our population has been increasing at the rate of 10 per cent. per decade. At the same time, however, we have been importing, and that largely.

A writer in the London *Times*, who went at length into the subject recently, stated that America contributes about 15 per cent. of the total animal food consumed; and it is well known that very large supplies come from Dutch, Spanish, and other European ports. Another writer of authority in the *European Mail* of the 1st December, 1882, goes so far as to state that we import fully 2,000 tons a-day already from various parts of the world; but I feel doubtful about this. Taking these things into consideration, we may be thankful for the supplies from the colonies indicated by Sir Francis; but to all appearances, and putting in all the energy available, it must be the work of years before they can be available.

Meanwhile we have to depend very much upon America, the meat supplies of which were temporarily deranged during the late summer months. The laws of supply and demand are, however, bringing cattle again in vast numbers from their central and western cattle ranches to their seaboard, the excellent shipping facilities of which will, no doubt, be the chief source of our supply of cheap meat for a long time.

The history of mechanical refrigeration shows how, to use the words of Sir Frederick Bramwell, the utmost secrets of thermodynamics are applied to practical purposes—secrets, many of which have been made known by Glasgow men, and some of them distinguished members of this Society, amongst whom may be mentioned James Black, James Prescott Joule, W. Macquorn Rankine, and Sir Wm. Thomson.

OF SYDNEY.

RAT		Boiler Pressure.	Point of Cut Off Steam Cylinder.	Revolutions per Minute.	Air Pressure.	Point of Cut Off Expansion Cylinder.	TEMPERATURES. Air Temp. before entering Drying Pipes.	After leaving Drying Pipes.	Final Temperature of Air.	Meat Room. Average.	Sea Water.	Atmosphere in Shade.
F.	Di	Lbs.	Lbs.		Lbs.	Inches.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
	1.	...	...	...	...	...	...	...	...	26·5	...	...
	n.	...	...	...	...	...	...	...	...	33	61	...
5	n.	...	...	...	...	...	...	...	...	34	...	...
5		80	9	72	47	20	64	56	—69	28	...	...
5		76	9	68	45	20	64	56	—105	25	..	...
5	n.	...	...	...	...	..	..	...	...	34	..	...
3		...	...	...	...	...	...	...	...	35·5	...	...
3	n.	...	...	...	..	...	...	...	...	36	61	...
5	n.	78	9	68	45	20	63	57	—70	29·5	...	..
	n.	...	...	...	...	...	...	..	...	38	...	...
		...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	39	61	...
	n.	...	...	...	...	...	...	...	...	32	...	...
		78	9	68	44·5	20	63	56	...	32	...	...
	n.	...	...	...	...	...	...	...	...	36	...	..
		..	...	...	...	...	...	...	...	38	...	...
	n.	...	...	...	...	...	..	...	...	38	61	...
	n.	..	...	...	...	...	...	..	...	39	...	...
		80	9	70	45	20	63	54	—64	34·5	...	...
	n.	...	...	...	..	...	..	...	...	38	...	...
	n.	...	...	...	...	...	...	...	...	39	61	...
	n.	80	9	72	46	20	63	54	...	32	...	...
	n.	...	...	...	...	...	...	...	...	39	...	...
	m.	..	...	...	...	...	...	...	...	39	60	...
		80	9	70	45	20	63	55	—70	30·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	40	61	...
	m.	78	9	70	45·5	20	63·5	57	...	28·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	62	...
	n.	...	...	...	...	...	...	...	...	39·5	...	...
		80	9	72	46	20	63·5	57	—65	33	...	...
		...	...	...	..	...	...	...	...	30	...	...
		...	...	...	...	...	...	..	...	8·5	...	...
	m.	...	...	...	..	...	...	...	...	36·5	...	...
D		80	9	74	47	20	63	55·5	—70	30	...	...
		80	9	73	47	20	63	55	...	29	...	...
	m.	...	...	...	...	...	...	...	...	25	61	...
		...	...	...	...	...	...	..	—90	26	...	...
	n.	...	...	...	...	...	...	...	...	36	...	...
	m.	78	9	70	46	20	62	56	...	28	60	...
3	n.	...	...	...	...	...	...	...	...	38	...	...

3 feet Rooms cooled measure internally 100 feet × 80 feet × 10 feet 6 inches, equal to
duced 17th to September 2nd reduced the Meat room and maintained it at an average
on Se hours daily.

(Signed) JOHN REID, *Engineer.*

run off continuously by automatic traps, air being actually dried by compressing it in contact with water, removing the water and expanding it.

3. Direct injection is the quickest and most effective method of cooling air to the temperature of the water, which is a condition necessary to the working of a machine with the least expenditure of power.

4. Injection of a shower of water into freshly-compressed air tends to settle the fog caused by the sudden condensation of the invisible atmospheric vapour, thus facilitating its removal by traps.

5. That whilst the direct injection of water is desirable for cooling the air to the temperature of the water, it is not absolutely essential, if the compressed air be passed through a sufficient number of pipes surrounded by cooling water, the ultimate result in either case being that the compressed air can only be reduced to the temperature of the water, which is not sufficient to liquefy the vapour usually contained in the air, except the air pressures employed be excessively high—which is fatal, according to the first principles of thermo-dynamics, for working a machine economically.

6. That every lb. of vapour unnecessarily condensed liberates as much heat as will raise about four thousand times its weight of air 1° Fahrenheit, and that air absolutely dry is a condition that would abstract the fluids of animal tissue, and indeed is a phenomenon unknown in nature, the degree of humidity being generally over 50°, even in what is, in common parlance, called "dry air."

7. That a convenient way of liquefying such vapour is to apply a portion of the cold air produced by the machine to the external surface of the pipes or other vessels conveying the compressed air already cooled by water to the cylinder in which it is to be expanded, the liquid condensed in this way being removed by automatic traps.

Still dealing with machines intended for ships' provisions, I will direct your attention to Fig. 4, which represents in plan and elevation a machine which was exhibited at the Naval Exhibition in full working order last May, and which pattern has been adopted for the largest steamship afloat, the *City of Rome*, and for the new steamer, *Normandie*, of the Compagnie Transatlantique Générale of Havre.

The air is compressed in the air-pump, P, deprived of its heat by compression in the tower, T, passes through the horizontal moisture-depositing pipes packed in the sole-plate, and is finally expanded in the act of doing work in the cylinder, E, from whence it is conveyed round the outside of the metallic cells containing the water required to be frozen for table use, and then is delivered into the chamber containing the meat and provisions. The length of this machine is 12 feet, its breadth at the point P is 3 feet, and at the point E is 4 feet, and its height is such that it will go 'tween decks of any vessel. Its best position is adjoining the main engine-room, but as the stewards' departments are frequently elsewhere, the machine is sometimes placed on the upper deck, or in the position usually occupied by the old ice-house. The air delivered by these machines is so dry, as well as cold, that calico or paper hung up in it ignites readily on application of a flame, so that the provisions are prevented from getting into the slimy condition which they assume when packed in ice. The provision-room of a large steamship measures internally perhaps 2,000 cubic feet, including the space necessary for storing the wines, salt meat tanks, etc. This pattern of machine is proving a very useful one in another direction, for, by arrangement with Messrs. Crossley Bros., the makers of the Otto gas engines, they are being constructed to be driven by gas instead of by steam. The air-pump in this new machine is placed in the position of steam cylinder, Fig. 4, and the gas motor cylinder takes the place of the air-pump, P, on same diagram. Such machines affording a cooling power equal to what could be obtained by the use of half a ton or a ton of ice per day, are now being made for retail shops, country mansions, etc.

Turning now to diagram 3 you have the favourite type of machine for doing work on a large scale. In this case there are two air-compressors, one being attached to piston-rod of steam cylinder and the other to piston-rod of expansion cylinder. A large number of these machines have been constructed as follows:—Each air-pump is 16 inches diameter and 2 feet stroke; the steam cylinder is 18 inches diameter and 2 feet stroke; and the expansion cylinder 17 inches diameter and 2 feet stroke.

Such machines are large enough to carry 600 cattle divided into quarters, and to keep the same within two degrees of the freezing-point of meat, in the Atlantic traffic. Both machine and cattle can be packed in the 'tween decks of a steamer of say 100 feet

long, 40 feet wide, and 6 feet high, of which the machine will occupy 7½ per cent. Cargoes of this kind arrive in Glasgow every week.

Still larger machines have been used for the bringing of frozen meat from Australia and New Zealand, and in which the compressors measure 21 inches diameter and 2 feet stroke.

On diagram 5 is a section of one of Messrs. Patrick Henderson & Co.'s ships fitted up, the end view of the engine appearing in top left hand corner, and the space cooled being not only the 'tween decks, but the lower hold of the forward half of the vessel.

This vessel is a sailing vessel, called the *Dunedin*, which recently brought 175 tons of mutton from New Zealand, kept in a frozen state during the whole voyage of 98 days, the meat having been shipped by the New Zealand and Australian Land Co., Limited; and, in a book of information recently published by the able general manager of this company, W. S. Davidson, Esq., of Edinburgh, is to be found the following description of the shipment:—

The sheep were killed on the Company's Totaro estate, and were conveyed about sixty miles in ventilated railway vans, to the ship's side, where they were hung up on hooks in the refrigerating chamber until stiff with frost, after which they were put in calico bags and passed into the lower chamber, where a temperature of 10° below zero soon made them as hard as wood, and ready to be stowed away in layers as close as they could be packed. Loading commenced in January, 1882, and within a month the shipment of 4,909 carcases of sheep and 22 pigs were all safely stowed away, hard frozen. The *Dunedin* sailed from Port Chalmers on the 15th February, 1882, and arrived at the London Docks after a long passage of 98 days. Notwithstanding this, and the exceptionally hot weather encountered in the tropics, where the vessel was becalmed for a long time, the meat arrived in splendid condition, and within a fortnight the whole was disposed of at satisfactory prices.

The Smithfield salesmen were much surprised at the quality and condition of the sheep, and in fact every one who saw them admired them very much. As specimens of what the country is capable of, some 30 large sheep, weighing from 140 to 162 lbs. each, were sent. Not only was the experiment a thorough success from a scientific point of view, but it was also very satisfactory financially speaking.

Altogether they brought				£8,009	14 3
The charges were—					
Calico for bags, . .	£91	8	9		
Keeping meat frozen after arrival in the Docks, .	43	11	9		
Freight, ...	2,779	9	5		
Insurance, . . .	414	13	9		
Other expenses of discharging, carriage to Smithfield, &c.,	463	18	8		
				3,793	2 4
				£4,216	11 11

Netting 3·23d. per lb. for the sheep.

Although many of the carcases had been frozen four months, they were bright and clean-looking as newly-killed mutton.

The vessel *Dunedin* has gone out again to New Zealand, together with a sister ship of the same line, called the *Lady Jocelyn*, fitted up with the same-sized machines, the quantity of meat to be increased to 250 tons or thereabouts for each vessel.

In the case of the steamships of the Orient Line and other steamers, the cold chambers for containing the meat have been constructed in the 'tween decks of the ship, so that their form varies; but the method of building them consists of lining the walls, the floor, and the roof of the meat-chamber with wood-work containing hollow spaces filled with wood, charcoal, or shavings. It is found that 7 inches thick of such lining forms very fair insulation; but, in the case of tropical ships, it is frequently made 10 or 12 inches thick. It is also found that the larger the quantity of meat brought over, the more economically can the work be done. Thus the prime cost of the machinery for carrying a pound of meat is 25 per cent. less when a ship is fitted up to carry 1,000 tons instead of 500 tons, and there is a further gain of 10 per cent. in the less packing space required.

A large-sized steamship, costing say £100,000, could have its entire cargo space refrigerated by machinery costing about £10,000, so that it may be safely assumed that any big ship could be adapted to carry a frozen instead of an ordinary cargo at an increase on the prime cost of 10 per cent. or 15 per cent.; and this is the proper way of looking at it, because the machinery is as solid and substantial as the vessel's engines.

The largest machine which I have been connected with is one constructed for land purposes, and which was sent out to Sydney some months ago, after being tried in the shops. Its erection is

now completed, and the diagram on the walls shows the nature of the building which it is employed in cooling, the floor area of which is 80 feet by 100 feet.

The floor of this room is constructed of concrete, upon which are bedded 3-inch planks by means of asphalt. The sides of this room are of masonry, but the inside is lined with several inches of thin boards, an air space of an inch or two being left between each layer of boards; the ceiling is covered a foot deep with sawdust, and over that the usual rafters of a double lean-to roof.

It has been designed for cooling the whole of the meat supply of Sydney to 40° in the height of summer, the air then being above blood heat, and prevents the stiffening of the meat we are accustomed to in this country called "Rigor mortis," and without which the meat decomposes in twelve hours.

The machinery supplied to do this work consisted of a pair of air-compressers of 24 inches diameter and 3 feet stroke, an expansion cylinder of 25½ inches diameter, and a steam cylinder of 27 inches diameter and 3 feet stroke, and the whole work has been done under the superintendence of the London consulting engineer of the colony, Mr. John Fowler, C.E., of Forth Bridge celebrity, and under the inspection in the colony of the Government engineer there. The official trial has lately taken place, when the machine run for thirty days, and it was found that the air discharged fresh from the machine registered as low as 105° below zero Fahr.—that is, its temperature was 137° below freezing point registered with an alcohol thermometer, as mercury itself freezes something like 40° below zero. This very low temperature is fully 50° below the lowest temperature that has ever been recorded by any navigator in the Arctic regions; but it is not the limit of these machines, as by increasing the working pressure of the air, or, in other words, the degree of compression of the air, which, with the Sydney machine, was 45 lbs. per square inch, still lower temperatures can be obtained.

The lowest temperatures which have been obtained in scientific laboratories has been about 200° below zero, but it is believed that before 460° below zero is reached, all known gaseous matters would be absolutely solid.

The fact of air being so excessively low in temperature when first liberated from the machine does not in any way interfere with keeping a regular temperature in the cold chambers—in fact a temperature so regular that nothing even in the most equable

climate can possibly be compared to it. An examination of thousands of recorded observations of the Bell-Coleman machines traversing the Atlantic show that the temperature of the chambers does not vary 3° during a voyage, being much less variation than the difference between the hours of morn and even of any ordinary winter day.

This even temperature is maintained by distributing the cold air by pipes carried along the top corners or roof of the chamber, and having outlets at regular intervals, the velocity or flow of the air being regulated by the speed at which the machine is worked. There is no big blast or current of air perceptible at these outlets, the cold air tranquilly displacing the warmer atmosphere as easily as cold winter air permeates through the chinks of windows and doors of a sitting or drawing room, and the atmosphere is no more disturbed than in such cases. It follows from this that a chamber can be kept at any temperature deemed desirable—thus, 20° Fahr. is thought a very desirable temperature for bringing meat long distances across the tropics, 28° Fahr. is thought desirable for bringing meat from America, and 40° Fahr. for preserving town meat in public abbatoirs; whereas in India the temperature required for sitting rooms is perhaps 70° or 80° Fahr. There is no difficulty in meeting any of these conditions; and, in regard to India, I give you a calculation I submitted to the Institution of Civil Engineers. As regards public buildings, hospitals, etc., experience has demonstrated that machines of sufficient power to cool 100,000 cubic feet of air per hour, through a range of 150°, can be worked with a steam cylinder indicating 100 to 150 h.p. by the consumption of one-fifth of a ton of coal an hour. The attendance upon such a machine would not cost more than 1s. 6d. per hour, the lubrication 6d., and the interest on capital, say, 1s. per hour, so that the whole 100,000 cubic feet of air could not cost more than, say, 8s. 4d.; but being so excessively cold, it could be mixed with 400,000 cubic feet of uncooled air, and this would then give a supply of air per hour to 1,000 people, at the rate of 500 cubic feet per head per hour, cooled 30° below the external atmosphere—a very excellent ventilation at the cost of one-tenth of a penny per head. Whilst on this subject of figures, it may be interesting to state that the cost of cooling the meat in the Sydney abbatoir has been calculated to be $\frac{1}{50}$th of a penny per lb. of meat cooled per day, allowing interest on money at 5 per cent. and depreciation at 5 per cent., and the working

expenses of the machine. And in further reference to this subject, Messrs. Hennicke & Goos, civil engineers of Hamburg, Germany, have recently published some figures relating to powerful Bell-Coleman machinery erected at the abbatoirs of Mr. Koopman, who supplies large quantities of breakfast bacon for the London markets.

To measure accurately the work being done by a cold-air machine it becomes necessary to take observations—1° of the horse-power being exerted by the steam cylinder, 2° of the temperature of the compressed air previous to expansion, 3° of its temperature immediately after expansion, 4° of the terminal pressure of the air of the expansion cylinder, as read off an indicator card. The calculation presupposes that the compressed air has been cooled to the temperature of the water available for cooling it, and it is then as follows:—First, to arrive at the weight of a cubic foot of air at the end of the stroke, let

W = weight of cubic foot of air in lbs. avoirdupois.
P = pressure of air in lbs. absolute per square inch as read off an indicator card taken of expansion cylinder.
T = the absolute temperature in degrees of Fahr. at the moment of discharge.

Then $$W = \frac{P \times 2{\cdot}704.}{T}$$

Having now ascertained the weight of a cubic foot of air, it merely remains to multiply it by the number of cubic feet swept out of the cylinder in a given time, say one hour, then by the specific heat of air, and the weight of water is arrived at which could be cooled through the same range as the air has been cooled. This can then be calculated as heat units.

The formula now becomes

$$w = \frac{W \times S \times R,}{L}$$ in which

W = weight of air discharged per hour.
S = specific heat of air (0·23).
R = range of cooling in degrees Fahr.
L = latent heat of ice.
w = lbs. ice at 32° produced from water at 32° per hour.

Returning, however, to oceanic food refrigeration, which is no doubt the most important application of refrigerating machinery that we are acquainted with, it seems abundantly clear that when once meat is frozen it will keep indefinitely, and when thawed it

is practically in the same state as at the moment before freezing—that is, if the thawing takes place in a dry atmosphere—otherwise the aqueous vapour contained in the warm air into which the meat is immersed for thawing precipitates upon the surface of the meat as moisture, just as dew precipitates upon grass or shrubs cooled by radiation into space during the night time.

There has been about 4,000 tons of Australian and New Zealand frozen meat delivered into Great Britain by means of cold air machines up to the present date.

On the authority of Sir Francis Dillon Bell, who read an interesting paper recently to the Royal Colonial Institute on the resources of the Australian Colonies, it is claimed that Australia and New Zealand could export to England 1,000 tons of meat daily, and maintain this *ad libitum*. This statement of Sir Francis is probably correct, when we bear in mind their extraordinary rapid rate of development.

It appears that the commerce of Australasia is now of the value of £100,000,000 annually, an amount equal to the whole commerce of the United Kingdom at the accession of Queen Victoria.

In these far-off countries they have spent £56,000,000 in railways, which are ready to bring some of the 65,000,000 sheep, or 8,000,000 of cattle, they possess to their splendid seaports. The question of making arrangements, however, for the importing into this country of such a quantity as 1,000 tons a-day is a very serious one.

As one ton dead weight of meat requires 120 cubic feet gross of space in a ship, the whole of the steamers that were built in the United Kingdom during the last 12 months would not be too much for carrying it, supposing they were all put upon the traffic. These steamers were 474 in number and 343,361 in tonnage; or, to put it in another way, supposing all the steamers of the Cunard, the Anchor, the Guion, the State, the Inman, the National, and the White Star Lines, which usually carry passengers to New York, were put on this trade, they couldn't bring over this quantity of meat, and there would be the very awkward question as to the kind of cargo they could carry on the outward voyage.

The metropolitan meat markets in London are said to get through about a thousand tons of meat per day, and the average consumption of meat per head in the United Kingdom is stated, in M'Culloch's "Commercial Dictionary," to be about 100 lbs. per head per annum, so that we may fairly conclude the total

consumption of meat in the United Kingdom is something between 3,000 and 5,000 tons per day.

On the other hand, according to the Board of Trade agricultural returns in the year 1874, we had 30,000,000 of sheep in the United Kingdom. They have now diminished to 24,000,000, and the amount of cattle has been stationary for some time, whilst our population has been increasing at the rate of 10 per cent. per decade. At the same time, however, we have been importing, and that largely.

A writer in the London *Times*, who went at length into the subject recently, stated that America contributes about 15 per cent. of the total animal food consumed; and it is well known that very large supplies come from Dutch, Spanish, and other European ports. Another writer of authority in the *European Mail* of the 1st December, 1882, goes so far as to state that we import fully 2,000 tons a-day already from various parts of the world; but I feel doubtful about this. Taking these things into consideration, we may be thankful for the supplies from the colonies indicated by Sir Francis; but to all appearances, and putting in all the energy available, it must be the work of years before they can be available.

Meanwhile we have to depend very much upon America, the meat supplies of which were temporarily deranged during the late summer months. The laws of supply and demand are, however, bringing cattle again in vast numbers from their central and western cattle ranches to their seaboard, the excellent shipping facilities of which will, no doubt, be the chief source of our supply of cheap meat for a long time.

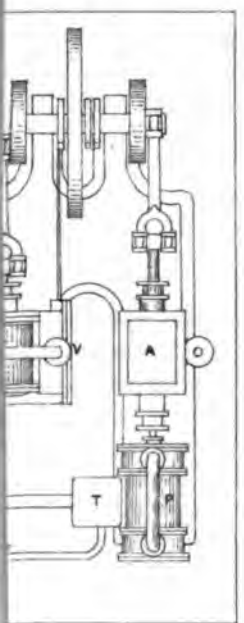
The history of mechanical refrigeration shows how, to use the words of Sir Frederick Bramwell, the utmost secrets of thermodynamics are applied to practical purposes—secrets, many of which have been made known by Glasgow men, and some of them distinguished members of this Society, amongst whom may be mentioned James Black, James Prescott Joule, W. Macquorn Rankine, and Sir Wm. Thomson.

OF, SYDNEY,

RAT		Boiler Pressure.	Point of Cut Off Steam Cylinder.	Revolutions per Minute.	Air Pressure.	Point of Cut Off Expansion Cylinder.	TEMPERATURES.					
							Air Temp. before entering Drying Pipes.	After leaving Drying Pipes.	Final Temperature of Air.	Meat Room: Average.	Sea Water.	Atmosphere in Shade.
F.	D	Lbs.	Lbs.		Lbs.	Inches.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
	n.	...	...	...	...	...	...	...	...	26·5	...	...
	n.	...	...	...	...	...	...	...	...	33	61	...
	n.	...	...	...	...	...	...	...	...	34	...	...
		80	9	72	47	20	64	56	—69	28	...	...
		76	9	68	45	20	64	56	—105	25	...	...
	n.	...	...	...	...	...	...	...	...	34	...	...
		...	...	...	...	...	...	...	...	35·5	...	...
	n.	...	...	...	...	...	...	...	...	36	61	...
	n.	78	9	68	45	20	63	57	—70	29·5	...	...
	a.	...	...	...	...	...	...	..	...	38	...	...
		...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	39	61	...
	n.	...	...	...	...	...	...	...	...	32	...	...
		78	9	68	44·5	20	63	56	...	32	...	...
	n.	...	...	...	...	...	...	...	...	36	...	..
		...	...	...	...	...	...	...	...	38	...	...
	n.	...	...	...	...	...	..	...	...	38	61	...
	n.	..	...	...	...	...	...	...	...	39	...	...
		80	9	70	45	20	63	54	—64	34·5	...	...
	n.	...	...	...	...	...	..	...	...	38	...	...
	n.	...	...	...	...	...	...	...	...	39	61	...
	n.	80	9	72	46	20	63	54	...	32	...	...
	n.	...	...	...	...	...	...	...	...	39	...	...
	n.	..	...	...	...	...	...	...	...	39	60	...
		80	9	70	45	20	63	55	—70	30·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	40	61	...
	n.	78	9	70	45·5	20	63·5	57	...	28·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	...	...
	n.	...	...	...	...	...	...	...	...	38·5	62	...
	n.	...	...	...	...	...	...	...	...	39·5	...	...
		80	9	72	46	20	63·5	57	—65	33	...	...
		...	...	...	..	...	...	...	...	30	...	...
		...	...	...	...	...	...	..	...	8·5	...	...
	n.	...	...	...	...	...	...	...	...	36·5	...	...
0		80	9	74	47	20	63	55·5	—70	30	...	...
		80	9	73	47	20	63	55	...	29	...	...
	n.	...	...	...	...	...	...	...	...	25	61	...
		...	...	...	...	...	...	..	—90	26	...	...
	n.	...	...	...	...	...	...	...	...	36	...	...
3	n.	78	9	70	46	20	62	56	...	28	60	...
	n.	...	...	...	...	...	...	...	...	38	...	...

3 feet Rooms cooled measure internally 100 feet × 80 feet × 10 feet 6 inches, equal to
duced 17th to September 2nd reduced the Meat room and maintained it at an average
on Se hours daily.

(Signed) JOHN REID, *Engineer.*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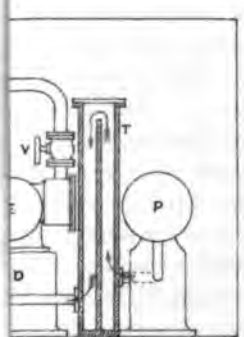
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XI.—*On the Clauses in the Draft Glasgow Police Bill which have reference to the Prevention and Mitigation of Disease.* By EBEN. DUNCAN, M.D., F.F.P.S.G.

[Read before the Society, 6th December, 1882.]

THE first twenty-five sections of the Draft Glasgow Police Bill deal with Police regulations for the government of the city, which have no bearing upon sanitation or public health. The 26th section is the only section of the Act which deals exclusively with matters relating to the public health and to the prevention of epidemic diseases. It is divided into five sub-sections. In sub-sections 1, 2, 4, and 5, the alterations and additions which are made upon the Public Health Act of Scotland are, with one exception—to which I shall subsequently refer—comparatively unimportant, and the amount of disease which can be prevented or mitigated by their operation will be a very small percentage of the average amount under present conditions. Sub-section No. 1 contains four clauses which define the sanitary powers of the Police Board and of its officers. These powers are substantially the same as those given to every Local Authority by the Act of 1867. In sub-section No. 2, which relates to the removal of nuisances, the only important difference which I note is that such cases as the smoke nuisance, which, according to the Public Health Act should be tried before the Sheriff, according to the provisions of the Police Act are to be decided in a Magistrates' Court. This change in the administration of the clause is certainly not in the public interest, because many of the magistrates are themselves offenders in these matters, and will, consequently, be very unlikely to administer the law impartially. The case of a magistrate being tried by a brother magistrate for a smoke nuisance is not an unheard-of case in Glasgow. As the polluted state of the air of this city is one of the most important causes of disease and death

in the community, I hope that in the next Public Health Act for Scotland Glasgow will not be excepted from the common law of the land in this matter. I think, further, that the workman who neglects his duty, in the matter of careful and regular feeding of his furnace fire, should be placed under penalty for any proven act of carelessness, as well as the employer, who is at present solely responsible for the workman's negligence. The clauses of the Public Health Act which deal with the removal of nuisances are quite as comprehensive as those of the Police Bill, and in the Public Act, as in the Local Act, it is enacted that the owner of a house may be made liable and mulcted in a penalty for nuisances which have been originated by his tenant. Sub-section 4, which deals with the regulation of lodging-houses, differs in only one important particular from the section of the Public Health Act which deals with such places. It is enacted by the Local Act that not only must the lodging-house keeper notify every case of infectious disease to the Sanitary Authority, but also every illness which causes a lodger to be confined to bed for 24 hours. Sub-section 5 refers to unwholesome and adulterated food, and differs from the general Act in three important particulars—1st. It provides for the inspection of all dead meat brought into the city for consumption. 2nd. It enacts that not only the person in whose premises the unsound meat is found may be prosecuted, but also the original consigner or seller of the food, if it was unsound at the time of the sale. 3rd. It is enacted that a person who has knowingly concealed from the Sanitary Inspector unsound food, for the purpose of selling it, is liable to imprisonment for 60 days. We now come back upon sub-section 3, which deals specially with the prevention and mitigation of infectious disease, to which I wish to devote your special attention to-night.

Since the year 1867, in which the Public Health Act of Scotland became law, sanitary science has been advancing rapidly, and every fresh discovery as to the causation of disease has had an outcome in sanitary legislation. We find, therefore, on looking over the more recent Health Acts of England and Ireland that in these measures considerable additions have been made to the provisions of our Scotch Act of 1867. Some of the more important of these additions have a place in this Draft Bill. There are two directions, however, in which the promoters of this Bill seek to make fresh advances upon the latest Public Health Act—that of Ireland, which was passed by the legislature in 1878. It would be impossible to discuss

in one evening all the amendments on the Public Health Act of Scotland which are embodied in this sub-section of the Bill. I therefore desire to confine the discussion to-night to these two fresh departures in sanitary legislation. I refer to the clauses which deal with compulsory notification of infectious disease, and the clauses which are directed against the propagation of infectious diseases by milk.

The infectious diseases mentioned in the Act may be divided into two classes—(1st) those which are generally associated with well-known sanitary defects, and (2nd) those which are not so associated.

CLASS I.

		Insanitary Causes.
A	Typhus Fever. Relapsing Fever.	1. Insufficient Food. 2. Overcrowding. 3. Dirty and badly ventilated houses.
B	Cholera. Typhoid Fever.	1. Defects of drainage, and of other methods of disposal of human excreta, leading to tainted water or milk. 2. Dust of dried alvine discharges from previous cases disseminated through the air.

CLASS II.

Smallpox. Scarlet Fever. Measles. Hooping-cough.	Diseases which are propagated through air, food, or clothing, exposed to contamination by the exhalations from the patient's lungs or skin.

It is necessary to keep in view the various ways in which these diseases arise and propagate themselves, in order to understand the probable effects of the measures of isolation and disinfection which are intended to be employed by the sanitary authority. Let us take them up individually, and consider in each case what additional help may be got from compulsory notification. Past experience has shown us that outbreaks of typhus fever and relapsing fever are preventable if the sanitary authority does its duty—(1st) in rooting out the overcrowded fever dens which the ignorance and negligence of a former generation permitted to spread like cankers in the heart of the community, and (2nd) in providing the displaced

population with healthy houses and aiding them in times of poverty and distress.

My personal experience of typhus fever goes back for twenty years. I remember well the days before the City Improvement Trust did its great work of renovation, and how typhus decimated the crowded wynds and closes of old Glasgow. I can count up ten of my old fellow-students in the Glasgow University who died of typhus either in their student days or in the early years of their practice. At the present time so successful have been the combined efforts of the Improvement Trust and the Sanitary Department, that very few of the young doctors who graduated during the past eight or nine years have ever seen a case of typhus fever in their student days, and medical men may now practice for years in this city without seeing a single case of the disease. It was by the labours of such men as the late Dr. Alison, of Edinburgh, and Dr. Perry, of Glasgow—who pointed out the distinctive characters of the disease and so led to the discovery of its true causation—and by the intelligent action of the city authorities founded upon the knowledge so obtained, that typhus fever was so successfully dealt with. At the present time, when typhus fever breaks out in any part of the city, it is found to originate, as in the past, in some overcrowded, badly ventilated place, and it has now become a danger signal, drawing the attention of the authorities to overcrowded and filthy dwellings.

This table shows the percentage of deaths from typhus fever in Glasgow as contrasted with the towns in which notification of infectious diseases by the medical man or householder has been enforced since 1879:—

TYPHUS FEVER.

(Calculating the percentage on the total death-rate.)

	Glasgow.	Edinburgh.	Dundee.	Greenock.
1878	0·36	0·49	0·70	0·86
1879	0·47	0·64	0·60	1·08
1880	0·33	0·22	0·47	0·69
1881	0·39	0·46	0·37	0·74

You see from this table that Glasgow, which has hitherto trusted to general hygienic measures, and has got its knowledge of this disease principally from the house to house visitations of sanitary inspectors, compares very favourably with the towns in which notification has been enforced. The evidence of its continuance

in these towns, in larger amount than in Glasgow, shows that we cannot expect compulsory notification to help us much in stamping it out. We must look to the removal of the fever dens which still remain, and which were so graphically described a few months ago in a pamphlet issued by the Ruskin Club, for the final extinction of typhus as an endemic disease in Glasgow. I have no doubt, however, that, if by compulsory notification, or any other means, the sanitary authorities could get earlier information of such sporadic cases as that described by Dr. Russell in his report to the Town Council on Tuesday, some good would be done, and some disease would be prevented. It was stated in the Council that, had the clause compelling the medical attendant to report such cases been in force in Glasgow, the small outbreak which originated from that case would have been averted. But I would point out that the medical man who was called in did not seem at all sure that the case was one of typhus. He merely told the people that it would probably turn out to be so, and under the present clauses he could not have certified. I have no doubt, however, that such cases may occasionally arise, and that if we could have compulsory notification enforced upon both medical men and householder, without producing worse evils, some good might be done, and some disease prevented.

Relapsing fever arises in the same circumstances of poverty, insufficient food, and overcrowding. It is now a rare disease. Years pass without a single death being recorded from this disease in Glasgow. All that I have said with regard to typhus and the means which are likely to "stamp it out," is equally applicable to the case of relapsing fever—I need not, therefore, occupy your time any longer with it.

We now come to cholera and typhoid fever. The past history of these diseases proves that they most commonly arise in epidemic form when the water supply of a community becomes tainted with the alvine discharges of an imported case. When cholera prevailed in this country we had no knowledge as to the propagation of such diseases by tainted milk, otherwise I think we would have discovered milk epidemics of cholera as we have discovered milk epidemics of typhoid. In every respect the laws governing the spread of these diseases are alike. Cholera does not long continue in this country, because the climatic conditions are not favourable to the vitality of the cholera germ. We cannot give the sanitary measures which were adopted in consequence of its

invasion the credit of stamping it out, although we may fairly give them the credit of limiting its spread. The fact that typhoid fever is so prevalent among us shows that cholera may readily occur again; but owing to the improvements in the general hygienic arrangements of the country, and specially to the care which is now bestowed upon the water supply, we may confidently predict that it will never prove so deadly in the future as it has done in the past.

Numerous epidemics of typhoid fever have been traced to milk contaminated either by water from a well impregnated with typhoid excreta, or by exposure to the dust of typhoid excreta in the vicinity of a fever patient. It will clear the way for a consideration of the probable effects of compulsory notification in typhoid fever if we now take up the question—To what extent will the clauses in the Police Bill which deal with infected milk be likely to diminish milk epidemics of this fever? The clauses referred to are three in number. Clause 288 enacts that when, in the opinion of the officer of health or of a medical practitioner, the spread of infectious disease is attributable to milk supplied from a dairy, the keeper of that dairy must furnish to the sanitary authority the names and addresses of all his customers. The next clause (289) enacts that he must also furnish the names of the milk dealers and farmers from whom he receives his milk. Knowing the frailty of human nature, the framers of this clause have strengthened it by compelling the dairyman to prove his verbal statements by an appeal to his books and invoices. When, by means of the information so obtained, the outbreak can be shown to have been limited to this man's customers, and to have come from one of the farms from which his milk had been obtained, and when it is further shown that an inmate of this farm is actually suffering from the malady in question, the remedy proposed in clause 280 is the very selfish one that the sale of that milk is to be prohibited within the burgh of Glasgow until the patient who has given rise to all this mischief has been removed or has recovered, and the farm premises have been disinfected to the satisfaction of the medical officer of health. As far as the Glasgow authorities are concerned, the milk may go anywhere else. Let us test the value of these clauses in the case of typhoid fever. In the first place, typhoid fever has commonly a period of incubation of three weeks; and, in the second place, after the symptoms do

declare themselves, eight days elapse before the physician can certainly say that the disease is typhoid; so that, from the time that a given milk supply begins to be contaminated, four weeks must elapse before the sanitary authorities of Glasgow can get any certain knowledge that an extensive poisoning with typhoid germs has been going on. Another week may be occupied in investigating the epidemic and tracing it to its source, so that during five weeks disease and death are being dealt out to the community before the remedy which the wisdom of the sanitary authorities has devised can be applied. And what is the remedy? To stop the farmer from sending that milk to Glasgow until, in the opinion of the medical officer, the disease has ceased in that farm. Surely this looks very like locking the stable door when the steed is stolen.

Let us take the evidence of the tables of mortality :—

TYPHOID FEVER.

(Calculating the percentage on the total death-rate.)

	Glasgow.	Edinburgh.	Dundee.	Greenock.
1878, ...	1·41	1·68	1·30	0·92
1879, ...	1·09	1·20	0·60	0·70
1880, ...	2·13	1·10	0·76	0·69
1881, ...	1·37	1·28	0·68	0·47

The opinion to which these figures point is that, if we are to place any faith in diminution of the death-rate, the towns in which notification by the householder alone has been enforced, show the best results. In Edinburgh, in which notification by the medical attendant has been enforced, the amount of disease of this kind is as great as in Glasgow, and the mortality has not diminished since the Act came in force. I do not, however, place any importance on a temporary diminution of the death-rate from this disease, as showing any beneficial effect from this new factor in Greenock and Dundee.

The epidemics of typhoid which have occurred in Glasgow during the past eight years, and have been of sufficient extent and importance to make an exhaustive inquiry into their causation possible, have all been traced to milk contaminated with the excreta of a typhoid fever patient in some neighbouring dairy farm. I read a paper to this Society two years ago, in which I pointed out that a careful inquiry into these epidemics failed to show that in any case was there any extension of the disease so produced through

the agency of the drains and sewers. Taking as our premises the two facts which I endeavoured to prove in that paper—viz., 1st, That during the prevalence of the extensive milk epidemics which have occurred in the past eight years, although there was an unusually large amount of the typhoid poison circulating in the drains and sewers of Glasgow, there was no extension of the fever along the lines of drainage or into the neighbouring houses; 2nd, That in many instances the house-drains and soil-pipes in these neighbouring houses were very defective, and freely permitted of the flow of sewage gases from these soil-pipes and house-drains, containing the typhoid poison, into these houses—the obvious conclusion is that (in Glasgow) epidemics of typhoid fever do not now arise from the inhalation of sewer gases. I do not deny that dust particles of typhoid excreta may be carried back from our sewers, but on the bases of these facts I do assert that the cases of typhoid which are so produced must be comparatively few. Therefore, 1st, Because four or five weeks must usually elapse, after the poisoning of the community begins, before the Sanitary Authority can become acquainted with its cause. 2nd, Because the statistics of other towns in which the clauses proposed in the Glasgow Police Bill are enforced do not on the whole give any evidence of progressive improvement in the death-rate from this disease. 3rd, Because the poisonous particles which give origin to the bulk of the cases of typhoid are not propagated within the jurisdiction of the City Authorities, but come from without. And lastly, because typhoid fever is not an infectious disease in the popular sense, and may safely be treated at home without the slightest fear of its spreading, if the discharges from the bowels of the patient are properly disinfected. On these four grounds I hold that neither compulsory notification, nor the milk clauses in question, will materially diminish the prevalence of typhoid fever in Glasgow.

What will diminish it? Although that question need not be answered in connection with this argument, it has some bearing upon it.

Two years ago I was asked by a milk agent to visit with him some dairy farms from which he thought of taking the dairy produce to supply his customers in Glasgow, and in the suburb in which I live. He wished me to give him my opinion as to their sanitary condition. I visited five farms. They differed very much in their size, appearance, and surroundings, but they

all agreed in this, that the kitchen opened directly into the byre, and the byre opened directly into the milk-house. The result of this arrangement was—(1st) that a large proportion of the foul and heated air of the crowded byre was carried into the apartments occupied by the farmer's family, and (2nd) that the milk standing in the milk-house was also exposed to the foul vapours which emanated from the byre. I was informed that this is the usual arrangement in the West of Scotland. I also found that in these five farms the farmer's wife not only attended to domestic duties and nursed her children through the various ailments of early years, but also attended to the dairy. When her children were recovering from these illnesses they, no doubt, ran about the byre and milk-house attending on all the dairy operations. In one farm-house which I subsequently visited in a delightful situation on the top of a hill, open on all sides to a pure, bracing atmosphere, I found that the farmer was himself the sole survivor of a large family born in that house. One by one they had died of consumption of the lungs. The bedrooms in that house were very small, and they received, through the kitchen, the emanations of 30 cows. The water supply was got from a well sunk immediately under the wall of the byre in a porous soil which had become saturated with decomposing animal matter. Year after year they slept in a poisonous atmosphere, and daily they drank from a tainted well. The inevitable result was death except to the strongest organism. In a second dairy farm the well was sunk in the middle of the courtyard, and surrounded by the byre, the stable, the dungstead, and the privy. Four feet of the surface was made up of road metal, through which the animal impurities could gain easy access to the well. In a third there was no privy of any kind for the use of the inmates, and the surrounding ground was littered with every kind of dirt and filth. The water was got from a tile drain which opened on the hill side behind the house, and the receptacle for receiving the water was exposed to contamination by the children who ran about all over the place. There had been fever in that farm a month before my visit, and it is easy to see the dangers which the recipients of the milk from that farm-house ran at such a time. Well, it is from these insanitary farm-houses that the typhoid epidemics of Glasgow spring. But how does the fever get there? I pointed out, in the paper to which I have already referred, one of the great sources of sporadic cases of typhoid fever. It is to be found in the huge accumulations of

manure collected from the poorest and most diseased districts of Glasgow, which are deposited in various parts of the city, and part of which is thereafter conveyed to the very dairy district of which I have been speaking. I have no doubt that in many of the milk epidemics from which this community has suffered, Glasgow has only reaped what it has sown. The authorities in this matter are without excuse, because a remedy has been found in the great towns of the midland counties of England. As these towns have no outlet for their excreta in a tidal river, necessity has again been the mother of invention, and, by the valuable and ingenious appliances of Messrs. Fryer, of Nottingham, they have found a means of reducing this foul and dangerous material into valuable, useful, and harmless products. I can quite see that the Glasgow authorities cannot come forward with clean hands to advocate a reform in the health administration of the rural districts until they can say—We have swept away the nuisances at our own door and those which we formerly dealt out to you. To any effort on the part of Glasgow to attack the causes of our typhoid epidemics at their fountain-head in the rural districts of Scotland, the rural authorities at the present moment would have good reason to reply—"First cast out the beam out of thine own eye, and then shalt thou see clearly to cast out the mote out of thy brother's eye." It is painful to visit the manure depots of Glasgow, and to find the authorities still engaged in the separation of old boots, broken glass, and scraps of iron, and then mixing up the foul mass with ashes, and transporting it to the farmers to poison the country districts. I don't say that in this respect Glasgow is in any way worse than other towns of Scotland; but, in the light of the deputations which it has sent to other towns, and the years of discussion which it has devoted to this question, I do say that Glasgow ought ere this time to have taken a lead in this important reform.

Up to this point the diseases in my list are most efficiently prevented by removing the bad sanitary conditions with which they are associated.

I now come to the last class of diseases—the spread of which is not necessarily associated with any well-understood insanitary conditions. These diseases spread by infection, in the popular sense of the word. It is to this class, if to any, that measures of compulsory removal to hospital, isolation, and disinfection are most specially applicable. Excepting the case of smallpox, it is only

by such means, in the present state of medical science, that we can hope to diminish them at all.

The past history of mankind teaches us that success has not hitherto attended efforts *to stamp out* by quarantine and disinfection such highly contagious maladies as scarlet fever, measles, and hooping-cough. The reason of this failure will be apparent if we consider the means which veterinary surgeons have been compelled to adopt to prevent the spread of similar diseases among the lower animals. I quote from a book entitled *The Four Bovine Scourges*, recently published by Mr. Walley, the Professor of Veterinary Medicine and Surgery in the Dick Veterinary College in Edinburgh. He says—"No temporising measures are of avail in suppressing cattle plague, and it can only be annihilated by the absolute destruction of every living animal which is the subject of the disease, or which may have been in contact with affected cattle; and not only so, but by the destruction, when practicable, of everything which is contaminated, or may be supposed to be contaminated, with the virus of the disease." Again, in speaking of pleuro-pneumonia, he says—"In its suppression slaughter, isolation, and external and internal disinfection can alone be relied on, with arrest of all movements to and from infected districts."

Now, gentlemen, scarlet fever and measles are quite as contagious as cattle plague and pleuro-pneumonia. Even if measures of slaughter were not necessary to success in an attempt to stamp out such diseases, and if we could succeed by the rigorous isolation and disinfection of every case, and by placing an infected district in quarantine, I don't think that society is yet prepared to allow the Town Council of Glasgow to apply such drastic remedies. If we are to take any lesson from the past history of mankind, the only measures which will succeed in stamping out these diseases will either take the direction of the discovery of a vaccine, as in the case of smallpox, or in the discovery of some medicine which will so alter the state of the blood of the patient that it no longer forms a suitable food for the disease germs. For such discoveries we must look not to administrative health officers, who never can be expected to do much in this direction, but to the unselfish labours of the medical practitioner. When the disease is dying out the thorough and universal adoption of such measures as isolation and disinfection, when thoroughly carried out, will hasten the process of final extinction, but must always bear a very

subordinate part. In the case of smallpox, you see from this table how successful vaccination has been in Glasgow. There have only

MORTALITY FROM SMALLPOX IN GLASGOW.

	Vaccinated.	Unvaccinated.
1878, . 2 deaths, . .	1	1
1879, . None, . . .	..	...
1880, . 2 deaths, . .	...	2
1881, . 2 deaths, . .	...	2

been six deaths registered in four years, and five of these persons were unvaccinated. The obvious conclusion is that thorough vaccination and revaccination in adult life are the proper remedies for stamping out this most loathsome disease. Neglect these remedies and, in spite of every measure of isolation and disinfection you can devise, you will have epidemics of smallpox reappear with their old virulence and malignancy. I believe the outbreaks of smallpox in London are largely the outcome of the agitation kept up by the stupid and ignorant Anti-Vaccination League.

Although I argue that the diseases in class II. will never be *stamped out* by any attempt at isolation and disinfection, however thoroughly carried into effect, I am quite agreed with the promoters of this Bill that these measures, if judiciously carried into effect, will do much good, and prevent the spread of much disease. We cannot wait till a vaccine has been discovered. That day may never come; although the discoveries of M. Pasteur in splenic fever and fowl cholera lead us to look in that direction for a solution of the difficulty. Let us, therefore, now consider the evidence furnished by the Registrar-General's mortality tables in those towns which have adopted this system of compulsory notification.

Let us take the next disease in the list—scarlet fever. Here is a table of the mortality from scarlet fever in the towns I have already referred to, and also in two English towns, one of which—Leicester—has adopted similar clauses to those in this Glasgow Bill. The other—Norwich—has adopted notification by the

householder, who is aided by a certificate written by his medical attendant, and handed to him to transmit:—

SCARLET FEVER.

(Calculating the percentage on the total death-rate.)

	Glasgow.	Edinburgh.	Dundee.	Greenock.	Leicester.	Norwich.
1878, ...	1·37	0·86	2·16	0.20	0·31	0·52
1879, ...	2·02	2·00	0·89	0·25	3·19	1·61
1880, ...	3·52	7·09	0·99	0·82	3·08	8·89
1881, ...	2·00	5·51	1·70	2·48	5·67	3·74

You see from this table that in every town in which notification has been enforced scarlet fever has increased in severity since 1879. I was somewhat surprised when I first saw these figures, because scarlet fever is a well-defined disease. The characteristic rash and sore throat are seen on the second day of the disease, before it has had time to do much mischief. This disease spreads, apart altogether from insanitary conditions, either by contagion through the medium of the air in close vicinity of the patient's body, or through some article of clothing or food which has been exposed to contamination in the immediate vicinity of the patient. When we find from the mortality tables, which cannot be mistaken, that in such instances such results follow either as the combined effect of the methods proposed in the Glasgow Police Bill, or in spite of them. When Edinburgh and Leicester in one fashion, and Greenock, Dundee, and Norwich in another fashion, attempt compulsory notification, isolation, and disinfection, and fail so completely, we should surely profit by their example, and look out for new and better methods in Glasgow. In order to do so we must find out what reasons can be given for the increased mortality. Why should such measures, which at first sight look so plausible and reasonable, lead to such a result? In the first place, I answer, notwithstanding the assertions of the town-clerks and the handful of health officers, on whose mere opinion, unsupported by any proof, the Select Committee of the House of Commons decided to support these clauses, this effort to coerce has led to the concealment of such diseases. The statements made by these men, that such cases of concealment do not exist, are as untrue as the statement that the Act in question has been an unqualified success. That such diseases are concealed in considerable numbers, on account of the fear which compulsory removal to contagious hospitals engenders in the minds of the lower classes, is proven by the universal

testimony of the medical practitioners who work among these people. The injudicious manner in which some of these health officers administer these clauses has in some places greatly aggravated this feeling. I have no doubt that these men act with the best motives and in the strength of their great zeal for the public interest, but still they sometimes act regardless of the feelings of the people and without sufficient regard for the interests of the unfortunate patients. Disputes with the medical attendant about such matters as the ability of the family to isolate the patient, and whether the patient is in a fit state for removal, have frequently occurred, and in many places the Act has been working "with great friction." I must honestly say that, after considering this point very carefully, I don't think the people are altogether without justification in objecting to go to the kind of epidemic hospitals which are offered to them. 1stly, The removal of a child suffering from a severe attack of fever to the Belvidere Hospital* of Glasgow—say from Cowcaddens, Anderston, or Tradeston—is not a proceeding which is likely to conduce to the child's recovery, nor is it conducive to the peace of mind of the parents—the distance making frequent visits to inquire after the dear one impossible. 2ndly, The whole principle involved in accumulating all the contagious diseases of the community in a great conglomeration of buildings on one spot of ground is utterly repugnant to every principle of wise sanitation. There can be no doubt that, under such circumstances, cases of a mutual exchange of diseases will happen in spite of the greatest care and vigilance on the part of the officials. I have the highest respect and esteem for the men who direct the affairs of these hospitals, and I know that whatever they can do

* Belvidere Hospital has been very carefully constructed, and is in many respects a very good specimen of its kind—probably one of the best in Britain. The principle of centralization which it embodies is, however, in my opinion, a very bad principle to carry into effect in a fever hospital. I make this protest against it now in view of the proposed extension of the hospital accommodation for fever cases in Glasgow in connection with some form of compulsory notification of infectious diseases. Separate hospitals for the most common forms of fever should be erected in the four quarters of the city within easy access of dwellings of the poor. To these, in the graver cases, the patient might be removed with safety. Belvidere would still remain serviceable for the large population of the eastern district of Glasgow. There the buildings for the different fevers should be further apart, and both buildings and airing grounds should be as carefully isolated from each other as the existing smallpox wards are at present isolated from the other fever wards.

to prevent the evils of which I have spoken, and to ameliorate the hard fate of the unfortunate inmates of these institutions and of their anxious relatives, will be done—and done well; but, nevertheless, the system is a bad one, and, in my opinion, should be altered. In speaking on this subject I wish it to be understood that I don't refer to Glasgow alone, but to the practice of most of the other large cities in the kingdom. I have not the slightest hesitation in saying that, by the system contemplated, of removal to hospital in all cases where the public interest is endangered, the mortality among the persons who suffer from these diseases will increase, unless some new kind of hospital accommodation is provided in the neighbourhood of the dwellings of the poor, in which the more serious cases can be treated. I think that, as it is in the public interest that these patients should be removed from their homes, the public should see to it that the interests of the unfortunate sufferers are protected in the best way that can be devised.

I need not weary you with any further objections to the methods suggested by this bill. I have not, however, by any means exhausted the subject, but I think all that I could say further has already been said in letters to the newspapers and otherwise. It only remains for me now to suggest the remedies which I consider best fitted to combat the spread of the diseases in question.

In Glasgow, I believe, the authorities will obtain the best obtainable results—1st. By increased vigilance in hygienic measures, and particularly in rooting out the closely crowded back tenements and rookeries which still exist scattered here and there throughout the city. 2nd. By erecting in the various parts of the city from which these fever dens have been rooted out, model tenements of houses for the working-classes, the topmost flats of these houses to be isolated from the dwelling-houses below, and converted into wards for the treatment of such diseases as scarlet fever, which, in the experience of medical men, can be treated in such places with perfect safety to the community, the roofs of the houses being utilized as airing and play-grounds for the children, where in good weather they may disport themselves in the open air. I would take scarlet fever as a test case, because, as I have already said, it is a well-defined disease, which is easily recognised at an early period, and because it is the most deadly and dangerous zymotic of childhood. Having selected that disease on these grounds, I would push every measure of isolation and disinfection, and, in

order to reconcile the parents of the child to these measures, I would not only permit them to see their children under proper precautions to prevent contagion, but I would allow the parent to choose his own medical attendant if he wished to do so. By such means the authorities could fairly test the powers of such measures as those proposed to be exercised in this bill. I would exclude measles and hooping-cough from the operations of this Act—1st. Because a large percentage of the cases of measles and hooping-cough are so mild in character that they are not recognised as such, and no medical man is sent for by the parents. 2nd. Because, even in well-marked cases, even a medical man cannot tell for some days that he is dealing with an infectious case, and yet during that period the disease is infectious. For these reasons, I believe that any attempt to deal successfully with measles and hooping-cough by the measures above advocated would end in failure, particularly when we consider, in the case of hooping-cough, the very long period which the disease takes to run its course, and during which it is infectious.

My last suggestion is that the householder should be educated to do his own duty in respect of notification of infectious disease, which I am satisfied will not be done if the responsibility is thrown upon the medical man, and that the money which the Town Council of Glasgow intended to spend in the remuneration of medical men for their certificates, amounting—calculating it on the basis of what is paid in Edinburgh—to at least £3,000 annually, should be expended in maintaining a staff of female visitors. A certain number of these female visitors might act in times of epidemic disease as matrons to the small detached hospitals which I advocate. The duties of these female visitors, and their value, may be gathered from the following excerpt, which I take from Mr. Macleod's last report on the operations of the sanitary department, p. 14:—

"The female visitor—appointed soon after the extension of "the staff in 1870, and placed amongst the lowest classes in every "district to instruct them as to cleanliness of person, children, "beds, and houses, and to point out how they and their children "in these respects may imitate and acquire the habits of the "better class, and the advantages to be derived by due observance "thereof—when she found slovenly housekeepers, giving them "practical lessons in sewing, and, where required, in bed-making,

"clothes-mending, and other domestic duties, pointing out the "propriety of making their little homes as comfortable as possible "for their husbands and families, inculcating the benefit to be "derived by regularly carrying out their turn of cleaning and "washing lobbies and stairs leading to their houses, noting down "the locality, number of inmates in each house; in obstinate "cases returning again and again, and, by kind persuasion, "persevering in her instruction until her aim of securing cleanli-"ness was obtained.

"She further noted in her report book any defect or want of "convenience, or any case of sickness she observed, and reported "the same to the district inspector, making herself generally "useful and valuable in her share of the work of the department.

"But unfortunately these officials, getting better appointments, "gradually resigned, and candidates for the vacancies with the "proper qualifications not having presented themselves, this "branch is now closed."

Here is a noble occupation for those philanthropic women whose hearts bleed for the miseries of poor humanity. What an incalculable amount of good could be done by a staff of educated women devoting their lives in this manner to the elevation of the masses in our crowded manufacturing centres. In times of epidemic disease what comfort it would bring to many a poor mother's heart to know that her child would be cared for by the friend who had been her constant adviser in her domestic troubles, and whose kindly presence had cheered and encouraged her in many a dark and despondent hour. In the life of such a female visitor the highest and purest form of practical Christianity would be exemplified.

In conclusion, in order to effect any permanent good in the direction of stamping out, or even of greatly limiting the spread of, zymotic disease, or of any preventable disease, large communities like Glasgow will find it to be their interest to agitate for a national system of sanitary reform. In the matter of sanitation, the needs of town and country are alike. The most urgent reforms are needed in our methods of local sanitary administration. The local sanitary authorities, urban and rural alike, must not only be differently organised, but must be subjected to the supervision and control of an active and educated central board—not a mere collection of poor law officials like the Board of Supervision. The members of

the central sanitary authority ought to be men who, from their special knowledge of sanitary science, are able to direct and guide the local authorities. They should not only have the knowledge and experience necessary to advise them wisely, but also the power to compel them to act on the advice given. The people of Scotland have suffered too long from the lethargy and incompetence of their present sanitary administrators.

After this paper was read on 6th December, a discussion took place, when Professor Gairdner, Dr. Russell, and Mr. Alexander Scott expressed their opinions. No report of this discussion was taken; but the discussion was resumed on 20th December, of which the following is an abstract:—

Dr. Russell—During last session of this Society I read a paper entitled "The Decade 1871-80 in Glasgow: a Sanitary Retrospect," which is printed in your *Transactions*, in which I submitted statistical tables which proved "that the most marked feature of the last, as compared with the preceding ten years, has been the diminished fatality of *all* forms of infectious or zymotic diseases. Only 7 in place of 20 persons out of every 10,000 of the population died of fever; only 1 in place of 2 died of small-pox; only 9 in place of 13 died of scarlet fever; 7 in place of 8 of measles; 12 in place of 15 of hooping-cough; 5 in place of 6 of croup and diphtheria; 8 in both periods from diarrhœal diseases." I also showed that this decrease was progressive; so that, in fact, if we divided the last ten years into two periods of five, and compared therewith the ten years 1861-70, in the case of every one of these diseases the last or most recent period of five years showed the lowest mortality. In April of this year I read a paper before the Epidemiological Society of London "On the Policy and Practice of the City of Glasgow in the Management of Epidemic Diseases, with Results"—the object of the paper being to connect "the policy and practice" with the "results" as cause and effect. That paper will appear in the next volume of the *Transactions* of the Epidemiological Society. Let me briefly describe the policy and practice which were fully developed only during the last five years which yielded the best results. The policy is peculiar to Glasgow among the cities and towns of the country. It is this. The Local Authority assumes the

undivided responsibility for the preventive treatment of all kinds of infectious disease. It recognises no distinction between pauper and non-pauper, between poor and rich. It levies rates for sanitary purposes, and every one living within the area of the rates is invited or compelled to accept of the hospital, washing, and disinfecting, and other services provided and maintained by the rates, without special charge in any case for any part of those services. We remove, for example, and treat the pauper from the poorhouse, and the servant or the master from the crescent or the square, and no special charge is made. I repeat that I know of no place in the kingdom where this unity and consistency of action against infectious disease exist.

Such being the policy, what is the practice? Here it is especially necessary to be brief. I shall confine myself to distinct statements made with deliberation and a full knowledge of the sanitary organisation and equipment of other towns. We have a large staff of officials of all grades, who prosecute the various departments of sanitary work, and are totally distinct from the police and the parochial functionaries. We have the most extensive provision of hospital beds in proportion to our population in the country, and we are engaged in developing our hospitals further, in number and in accommodation adapted to the social *status* of our patients. We are on the eve of completing the erection of what will be, we are told, the largest and best-equipped washing and disinfecting establishment in the three kingdoms. We have a reception-house for the temporary accommodation of families living in small houses, who have not that facility at home which is requisite for changing their clothing, and remaining at home while their house is being cleaned and disinfected. Greenock is the only other place, so far as I know, where such a provision is made; and we are ready to extend this provision to meet our necessities. The only sanitary institution in which Glasgow is defective is in the providing of mortuaries, which have not yet been erected, but which, in the Bill, we bind ourselves to erect.

The daily work of the department consists in the systematic application of this equipment to every case of infectious disease of the existence of which we are aware, to each in the fashion appropriate to the special disease and to the special circumstances of each case. The inspectors are provided with leaflets in simple language. One, which is put into the hands of the householder in

every infected house, states the law relating to infectious disease, and describes and enforces the duties following therefrom. Another has special reference to the preventive management of scarlet fever. In cases of enteric fever which are being treated at home under the care of persons who cannot afford to purchase disinfectants for the stools, these are supplied with directions for their use. If a case of smallpox is found the inmates are revaccinated, if they will submit, by the inspector who has been trained by the medical man who acts as vaccinator at a vaccinating station at the sanitary office and selects the lymph for the purpose. If there are unvaccinated children the vaccinator goes himself to the house and vaccinates them. Wherever children belonging to a family infected with an infectious disease of childhood are attending school they are warned not to continue attendance, and printed notices are sent to the school board and to teachers. As soon as the house is freed of infection another notice is sent, and until that is issued it is expected that attendance will not be permitted. In every case of infectious disease the rule followed is that the clothing must either be washed at the sanitary washing house, or a certificate must be produced from a medical man, certifying that disinfection has been carried out to his satisfaction. A similar course is followed with the house or infected apartment in it. I ought to have said that by arrangement with the registrars a constant supervision is exercised over the vaccination of all infants, and a systematic search for defaulters is maintained, so that there is probably no large city in which the Vaccination Act is more thoroughly enforced than in Glasgow. Animal lymph is procured from Brussels, whenever that will overcome objections on the part of parents, but that is seldom necessary.

Such being the machinery provided and maintained for the prevention of infectious disease in Glasgow, and such the liberal policy pursued in its application, how and to what extent do we discover the cases of disease to which it is to be applied?

(1) We know of *all* deaths, and we do so at once because daily communication is maintained with the registrars. (2) Guided by these deaths the inspectors prosecute house-to-house visitation, and so discover cases associated therewith. (3) A large number of cases are disclosed by the friendly hints of interested neighbours; few by the householders themselves, and those few chiefly by the very poor, who find that only their infectious sickness is cared for. The reports of such persons convey, in the absence of a medical

certificate, only an intimation of disease, the nature of which we must take steps to determine. (4) Every practitioner is supplied by us with printed notices in stamped envelopes addressed to me. These are used by no inconsiderable number of medical men, especially the younger men, to notify every case which occurs in their practice. The form bears that the case "ought to be removed to hospital," and the practitioner is requested to erase those words if he does not desire removal. The large majority of practitioners only notify rarely. Some will not notify in any case but continue attendance even in circumstances productive of great public injury. Others find themselves in a great strait between the impulses of their conscience and the conflicting interests of the patient, and resort to indirect methods of notification—as, for example, by anonymous post-cards written by themselves or by some third party. Frequently such gentlemen—as well as the younger men who bravely notify all cases to their great personal discomfort or even positive injury, have expressed to me their ardent desire that by law they should be relieved of their mental discomfort or the invidious comparison with their less dutiful brethren. (5) We get information also of many cases of infectious disease, especially in children, by printed forms supplied to the school board officers.

It is scarcely possible to estimate what proportion of the total cases of infectious disease in the city we never discover. We may say of smallpox and typhus a small proportion, of enteric fever and the infectious diseases of children by far the larger proportion. But if we regard direct and immediate knowledge, as distinguished from knowledge obtained indirectly after long delay, then but a small proportion of the cases of any infectious disease comes promptly under our cognisance.

Now, what are the circumstances under which this great mass of unknown, or imperfectly known, disease exists in Glasgow? The section of the Police Bill under discussion is that referring to the "Prevention and Mitigation of Disease"—that is to say, it prescribes what is to be done here and now for the prevention and mitigation of disease existing among the inhabitants living under the physical conditions of the day. The sanitary circumstance which controls all other in reference to the spread of infectious disease is the house accommodation. This gauges the relation of the infected to the healthy; and, whatever may be the nature and mode of infection, this is the cardinal fact in determining the chances of infection being communicated. In Glasgow 30 per cent. of the

the second five years 980, or 15 per cent. less, with a larger population. In the first period 23½ per cent. of the total deaths took place in hospital, in the second 31½.

Scarlet fever is another disease which Dr. Duncan thinks is entirely beyond the influence of practical sanitation. Here, again, I fall back upon what has been done by dealing with a small part of the total disease as evidence of what might be expected from dealing with the whole. Taking the same periods—in the first five years 3,657 persons died of scarlet fever in Glasgow, in the last five years only 1,293—a decrease of no less than 64½ per cent. In the first period only 8½ per cent. of the total deaths took place in hospital, in the second period 21 per cent. In the face of such facts as these, what becomes of the argument that notification is useless because nothing effectual can be done by the sanitary authority?

There are one or two matters to which I shall ask your indulgence only for a few words of reference. I adhere with emphasis to what I said after the paper was read about the milk clauses, and the manure question. The sanitary condition of the rural districts of Scotland cannot be reformed in a day. We wish powers suited to the present, let the distant future be what it may. Even if the Glasgow manure harms the rural districts, and through them harms us, still the remedy is the removal of those insanitary conditions. But our milk comes from regions far beyond the reach of our manure, and there is enteric fever over the length and breadth of rural Scotland, in regions where no manure either of town or village is ever seen. The farmer suffers, as every one does who lives in such places as Dr. Duncan describes, and his business occasionally makes him suffer more severely. I repeat that these milk clauses have nothing to do with panaceas or projects. They are intended to meet existing emergencies, and prevent or limit active mischief. And, I may add, they will be all the more effective if medical men will at once notify their cases of enteric fever.

Dr. FERGUS said—There was an objection to Dr. Duncan's paper of a want of practicality. He thought the paper was not the only thing that wanted practicality. He should like to have a return of all the cases reported to Dr. Littlejohn, Edinburgh, and what was done with them. He would also like to know from the sanitary authorities of this city what they were going to do with

the cases that were reported. That would be practical, and he did not think it was fair to accuse a paper of want of practicality unless the party making the accusation laid something more practical before them, and this he did not think Dr. Russell had done. He thought they should have been told what they were going to do, not only with smallpox and enteric fever, but with every disease under the schedule, and how it was to be done. That would have been practical. He was as anxious as any one to stamp out disease, and any one who was along with him in the Health Committee, or who had had any intercourse with him since, knew that what he had done in public had generally had that end in view; and the position he took up now on this question was still in the same direction. He had an idea that diseases could be stamped out; but were the authorities taking the best way of doing it? Some people were called "Amateur Sanitarians." He might be an amateur, but he had been a hard-working one. He had worked amongst the poorest of the poor in Glasgow for 19 years as a district surgeon, and there he got his experience. He said—and he said it from experience—that anything like the reporting of disease by the medical man would lead to the concealment of disease. He was willing, he was anxious, to help the municipal authority in every possible way in the stamping out of disease, but let them go about it in the proper way. Though they could not drive these people, they were easily led and influenced. Such a sum as £3,000 would employ thirty additional inspectors, going about among them at all times and under all circumstances, getting acquainted with the habits, wants, and modes of thought of the poorer classes, and thus they could get them to do anything they asked.

During the cholera epidemics in Glasgow inspectors were employed, but they had not been trained to the work, and the people had no confidence in them. The result was that, though some did their work well—very well—others did it very carelessly. Now, he would most particularly direct their attention to the remarks of the Lord Provost, which appeared in the papers of that day week. He took the liberty of quoting from the same book, and the evidence about the same towns, which had influenced his lordship and the Town Council in coming to their decision. The first of the towns his lordship had taken was Leicester. Now, it was a most unfortunate circumstance that any one desiring to urge sanitary reform should quote Leicester as an example, because Leicester, being notoriously the centre of non-vaccinators, required

this Act to stamp out smallpox. Compulsory notification by medical men was intended simply and solely to protect the Leicester people from the evils consequent upon their resistance to the Act of Parliament. Before leaving the subject of Leicester he would like to say that the year before compulsion in that town the ordinary death-rate was 21·6, and the zymotic death-rate 2·5. In 1880 the ordinary death-rate rose to 23·1, whilst the zymotic death-rate had gone up to 5·7. In 1881 the ordinary death-rate had fallen very nearly to its level, but the zymotic death-rate was 4·2. As he had just remarked, the Act was simply obtained so that Leicester might receive immunity from its own misdeeds.

The next towns the Lord Provost quoted were Blackburn and Bradford. As to the first they had not a particle of evidence, and as to the latter he was unfortunate in another direction, for, on reading his speech, it is perfectly obvious that he puts it under the category of those places where notification was compulsory on medical men, and such was not the case; indeed, the Medical Officer of Health attributes the success of the Act to the fact that notification is not compulsory on medical men. The next town he quotes is Birkenhead, and that is extremely amusing, because the Medical Officer of Health there (who had only held his appointment some three months) gives a very enthusiastic report, but the Committee of Health, he was glad to say, were more cautious. Liverpool had not adopted the Act; and, so far as Birmingham was concerned, an excerpt which he read from the *British Medical Journal* showed that the proposal was not adopted there.

He held in his hand the Report of the Royal Commission appointed to inquire respecting smallpox and fever hospitals, which certainly could not be accused of having taken evidence on one side. The Commission comprised—Lord Blachford, chairman; Sir James Paget, Mr. Edward Leigh Pemberton, Sir Arthur Alcock, Mr. A. W. Peel, Dr. Alfred Carpenter, Dr. J. Burdon Sanderson, Dr. William Henry Broadbent, and Mr. Jonathan Hutchinson. After taking an enormous mass of evidence on both sides, they came to sundry resolutions, one of which was:—"We think it, however, incumbent on us to state that, in our opinion, the prevalence of the disease in the Metropolis of which we have such deplorable evidence, is due, far above all other causes, to the neglect of this precaution—that if the practice of vaccination were general and very careful, the liability of the Metropolis to serious

epidemics of smallpox would cease—and that the more efficient administration of the vaccination laws is the only effectual means by which the recurrence of such epidemics as those of the last twelve years can be prevented, or their progress controlled." Well, they had all that in Glasgow, and the very improvement made in Glasgow in this respect—referred to by Dr. Russell—showed us that vaccination and revaccination had been successfully practised. Then the resolution the Commission came to on this special point about the reporting of disease was as follows:—"In effect it is only by the medical attendant, if any, that the diseases can be intelligently notified, since it is only he who can be presumed to know what it is, and who has no interest in concealing it. But it is represented that to impose this duty upon him directly and unreservedly would interfere with the relations which ought to exist between him and his patient, and might prevent the aid of a medical man being sought for at all. If this be so, it may be sufficient that the medical attendant should be required by law to furnish the persons in charge of a patient, or the owner or occupier of the house in which he lodges, with a certificate of the nature of the disease, stating whether proper isolation can or cannot, in his opinion, be secured without removal, and, when removal is necessary, stating also to what extent the case is urgent or severe. Every fresh case which occurs, even in the same house, should be the subject of a fresh certificate. The persons to whom the certificate is given should be in like manner required by law to forward it at once through the Medical Officer of Health, to the hospital authority, to be distinguished from the Guardians or Poor Law Authority on the one hand, and the Vestries or Sanitary Authority on the other, with whom it would rest to see that the sick person, if not properly isolated, is at once removed."

Preceptor MATHIESON said—It appeared to him that the writer of the paper was not aware that the present Glasgow Police Bill was based almost entirely upon the Glasgow Police Act of 1862. The Act was passed under Provost Clouston's *régime*, who had told him that it took nearly a year to discuss it, and there were then the same peculiar proceedings as are happening now regarding the present Bill. He thought that there was no necessity for drawing so much attention to the Public Health Act. He might state that it was found necessary, under the advice of the then Lord Advocate (Moncrieff), to have a special Act for Glasgow.

Dr. Christie said that, in the observations which he had to make as to the clauses in the new Glasgow Police Bill which have reference to prevention and mitigation of disease, he would confine himself to that clause which dealt with the notification of infectious diseases. Supposing, then, there was not a single case of infectious disease in the city, it would, nevertheless, be the duty of the Local Authority to promote hygienic measures to root out rookeries, &c., and it might even indulge in the employment of a staff of female sanitary missionaries. But, though the attic hospitals of the model tenements were an accomplished fact, the difficulty would still remain as to their occupants, and the question of compulsory notification, compulsory removal, and compulsory residence, would crop up as before. The Local Authority went further, and assumed that, though hygienic measures were perfect, though every rookery were rooted out, though they were living in Arcadia or Hygeia, they had nevertheless to do with cases of infectious disease, whether they existed in Park Quadrant or the Saltmarket. Infectious diseases might extend directly from the house of the rich man to that of the poor, or *vice versa.* If, then, it be the fact that the Local Authority had to do with infectious disease *per se* and directly, it followed that notification in some form or other was necessary. After pointing out the various ways in which notification might be effected, he said he was in favour of the mode proposed in the Police Bill. Legal notification could be made by a medical man, and by a medical man only. The notification made by a householder could merely be notification of suspicion. Were notification, therefore, laid upon the householder only, it would be necessary for the Local Authority, before it could move one step, either to send the Medical Officer of the City to certify the case, or to employ some other medical practitioner to do so. A more objectionable method could scarcely be formulated, or one more certain to cause perpetual friction. By the system proposed in the Bill, every case which had been seen by a medical man would forthwith be notified, while, by the system proposed by the Faculty, those householders who desired to conceal knew for certain what they formerly only suspected, or perhaps did not even suspect, that the case was infectious, and for selfish reasons they might defer delivering their certificate.

Dr. Christie also called attention to the Norwegian method of dealing with contagious diseases. The sanitary organisation of

Norway dates from May, 1860, so that ample opportunity has been afforded for testing the working of the system. When a parent or householder has in his residence a case of contagious disease he must report the fact at once to the President of the Board of Health. The attending physician is also required to report such cases. When a case of contagious disease is notified, the physician attending may advise its removal to hospital. In this case an order is at once issued, and the sick person is at once taken to hospital; his clothing, bedding, &c., are disinfected by dry heat, and the room is disinfected by burning sulphur. If the attending physician does not desire the removal of the patient to hospital, he confers with the city physician, or health officer, who has discretionary powers; but, in cases of smallpox or typhus, it is rare to permit the patient to remain out of hospital. Christiania, the capital, has the most ample hospital accommodation for each class of patients, the hospitals for smallpox, cholera, typhus, scarlet fever, and measles, being each separate and distinct. There is also an hospital where persons suspected of having contracted a contagious disease can be kept under observation without exposing them to danger.

In 1874 very stringent regulations were made as to disinfection, isolation, &c., and the result has been a diminution of the zymotic death-rate by about one-half—the contrast between the two decades, 1860-69 and 1870-79, being very remarkable.

The system has worked well in Norway for a quarter of a century, and it will do so also in this country, notwithstanding the hundreds of plausible objections which may be urged against it, in common with all other schemes for the public good.

Dr. MORTON objected to the proposed clauses. He had known Glasgow for many years, first as a student and then as a practitioner, and they had had epidemics for two or three years, in a great measure due to privation, up till the year 1847. Since that period Glasgow might be said to have been comparatively free of typhus fever—at all events, so much so that some practitioners educated within the last eight or ten years did not actually know a case of typhus when they saw it, and even then he had the greatest difficulty in persuading them that it was a case of typhus. He could state that from personal experience, and he believed that one of his colleagues took his students to Belvidere Hospital regularly for the purpose of enabling them

to know the disease when they met with it. He held, as regards compulsory notification of disease, that the *onus* of proof rested upon those who proposed this method. Dr. Littlejohn (the Edinburgh Medical Officer of Health) had written letters informing them of the brilliant results that had followed compulsory notification, but on looking at the mortality table during the last three years, the deaths from infectious diseases, instead of decreasing, had greatly increased. Now, he did not at all mean to say that the increase was due to compulsory notification, but on comparing statistics, it had not been shown to be a good thing in regard to Edinburgh. In Bradford, Norwich, and Nottingham, where the notification was by the householder, who received a certificate of the disease from the doctor, the plan had been found to work well. He maintained that the benefits of compulsory notification had not been proved to be of any special use, but they had evidence (from the towns just alluded to) that that form of notification worked remarkably well. They should try that system first, and if it failed, then let them try direct notification by the medical man. As to the question of finding suitable hospital accommodation, it was quite obvious that, if a patient had to be removed, it should be at as short a distance and as speedily as possible. They should, as Dr. Christie mentioned, have separate hospitals for separate diseases.

Dr. EBENEZER WATSON said that, on rising to speak in regard to this question, he felt at a great disadvantage, because the gentlemen who had spoken had made a speciality of sanitary medicine, while the nature of his practice debarred him from seeing much of this class of diseases. Nevertheless, he was much interested in the subject. He was very much pleased to hear the account which Dr. Russell had given of the sanitary machinery in Glasgow. However, Dr. Russell seemed to admit that it was a difficult thing, even a dangerous thing, for practitioners to notify disease, and that where it had been done it was to the disadvantage of the practitioners themselves. This was a very serious matter, especially to the younger members of their profession and to those who were practising in the poorer parts of the city. A curious circumstance had occurred to himself, which he thought would illustrate several points in this argument. A few years ago his family resided at the coast on the Firth of Clyde, and it so happened that an epidemic of scarlet fever arose in the village. He was first taken to see one of the children of the better class that was attacked

with the malady. The house in which the child lay was an excellent one, and possessed a considerable acreage of ground. He saw the patient, and was afterwards asked to see some of the children in the village who were suffering from the disease under very different sanitary circumstances. He communicated the matter to the doctor, who lived at some distance, and that gentleman was most courteous and attentive. On visiting the poorer children he pointed out to the people in charge what they should do in the way of sanitary matters. One of the cases was in the provision shop of the little village, and he had great difficulty in making the mother believe that her child had the disease. She resisted all his endeavours to get the child removed, and the disease spread, perhaps from that focus, to a considerable extent. "Well, now, what did I get for all my trouble? Why, the greatest possible ill-will and impertinence from the people. I really never was so ill-used in all my life; and if I had been a practitioner there they might not have left me then, but they would have had an ill-feeling towards me, and thereby placed me under great disadvantage."

The great objection to the medical clauses in the new Police Bill was not the smallness of the fees—although they were small enough—nor was it the trouble to the doctor, because he thought that was a very slight consideration; but it was that there certainly would be concealment of disease whenever the doctor was looked upon as a spy. The little story which he had told them showed how readily infectious disease would be concealed, and how the doctor would be regarded if he reported it. He thought, therefore, if this matter was to be re-discussed anywhere—whether in the House of Commons or elsewhere—that should be taken very seriously into consideration. He did not think that Preceptor Mathieson and others had remembered that it was not one or two medical men who spoke against this compulsory notification by the doctor, but that almost the whole of the profession had spoken or written against it.

Mr. J. Cleland Burns expressed himself strongly in favour of notification of disease. In the event of the householder being bound to give the notification, he should, he thought, be required to produce a certificate from the medical man. He maintained that the public must be protected by a proper medical certificate.

THE CHAIRMAN thought the feeling of the Society was that notification of some sort was necessary, or, at all events, advisable, in the interests of the public; but there was a difference of opinion as to whether it should be made by the householder on the certificate of a medical man, or by the medical man himself. For his part, he was of opinion that if notification by medical men were universal, the feeling against it might pass away. With regard to the city manure, he would like Dr. Duncan, in his reply, to state whether he had actual knowledge of the fact that it had produced typhoid fever in the case of farms.

Dr. EBEN. DUNCAN, in replying, said he would like, in the first place, to put himself right with the City Authorities. He had been connected with Glasgow all his days, and had its interests as much at heart as Preceptor Mathieson or Dr. Russell, and what he had endeavoured all through his paper was to show the City in a most favourable light. He had also demonstrated that in the statistical tables, given in his pamphlet, viz., that Glasgow compared most favourably with all other cities in which notification had been enforced. Dr. Russell had stated that they could not treat a case of typhoid fever in a house of two or three apartments. After an experience of twenty years, and after having paid great attention to typhoid fever, he was prepared to say he could do so without danger to the citizens. He also pointed out that this fever is frequently treated in the wards of general hospitals, and never gives rise to epidemics of typhoid among the patients of these hospitals—in fact, rarely spreads at all by atmospheric contagion—where any care is taken in the removal and disposal of the excreta of the patient. This brought him to another point, which was that at the present moment medical students in Glasgow had no opportunity of being taught the character of these diseases which they (the Authorities) wished to enforce notification of. Dr. Christie had mentioned the case of Christiania, where every kind of disease was treated in separate hospitals, but in Glasgow we have no such separate hospitals. His remarks about the existing arrangements for the treatment of fever in Glasgow had been called in question. What he desired to see in Glasgow was a system like that adopted by the authorities of Christiania. He was quite sure that any system of notification would be a dead failure if they did not make the hospital accommodation of a kind that would be suitable for the public and to which they would readily go. It had also been

said that he was a little inaccurate in regard to the milk question. When he inquired at those who made this objection what action they could take to prevent danger arising from cases of fever, the very existence of which they knew nothing of until it was revealed by the Glasgow epidemics, he was informed that the Glasgow Authorities were apprised of the cases of typhoid which occurred in the neighbouring dairy farms, by the sanitary inspectors of those districts, so that they could prevent the danger from arising by the help of the proposed milk clauses. He had taken the trouble to inquire at medical officers of health in five of the adjoining parishes, and they had informed him that in no instance did they or their sanitary inspector ever certify a case of fever to the Glasgow Authority, unless in the comparatively rare cases in which the patient required to be removed to the Glasgow Fever Hospital. Even in these cases it took eight or nine days before it was really known to be typhoid, so that a considerable time elapsed before the sanitary authorities could get certain knowledge that it was really so. These facts bore out what was said in his pamphlet. As to the manure question, he had taken considerable interest in regard to that manure depôt which is situated at the head of Eglinton Street. He had attended cases which he was quite sure were caused by particles emitted from the manure, and other medical men in the neighbourhood of it could bear testimony to this. As regards the farms in the country, they had diseases springing up in remote country districts where no possible chance of contagion could be thought of, and there was no doubt that particles of the contagious matter of typhoid fever and other diseases were sent to the rural districts in the manure, which they received not only from Glasgow, but also from the other towns and villages of Scotland, without any attempt at disinfection. He had given evidence as to this in the House of Commons six years ago, and read a paper on it before the Philosophical Society two years ago. It had been said he recommended a foolish system in advocating that Fryer's appliances should be employed to render the manure innocuous; but he would point to the fact that, where these had been in use in the great towns of the midland counties of England, extremely successful results had been brought about. He thought the meaning of the word "sporadic" was not clearly understood. Sporadic cases were not groups of cases in epidemics, but only occasional scattered cases, having no apparent connection with each other. In conclusion, he said that he had

never objected to the principle of compulsory notification of infectious diseases; but he held, in the first place, that the householder should be educated to do his own duty in notifying; and, in the second place, that the private medical attendant should be consulted in any question of removal to hospital. He did not think that it was right that such important matters should be left entirely to officials. He thought that the 21,000 medical practitioners, who had the care and responsibility of attending to the interests of the sick of the nation, should still retain some interest and responsibility in the sanitary arrangements which affected their patients. Any legislation which did not provide for this would be against the interests of progressive sanitation, and greatly against the welfare of the public.

XII.—*The Ships and Shipping Trade of Great Britain.* By Mr. Nathaniel Dunlop, Shipowner.

[Read before the Society, 14th February, 1883.]

Subject.—The subject of the paper which I venture to read to you is, Ancient and Modern Ships, with special reference to the applications of science in their structure and outfit, to which is added a chapter on the influence of legislation upon shipping; the value to the country of its foreign trade and maritime commerce; and the necessity of special protection being provided for the nation's shipping.

I.—Ancient and Modern Ships and their Recent Appliances in Navigation.

It cannot fail to have struck even the most superficial observer to what a wonderful extent science has been applied during the last few years in the various walks of commerce.

Within very recent times the man of science occupied a place apart from those who carried on the great industries of the country. Filling a chair or other special post of learning, his investigations and discoveries were confined to his laboratory or his study, and the results of his labours were generally regarded as more curious than practically useful. His expositions filled us with astonishment, for he showed to us the hidden causes of effects with which we were familiar; but his deep insight into the nature of things was seldom regarded as available in practical everyday work.

All this is changed; the man of science has a place in all our important occupations. No manufactory or industry of note is without its scientific expert, and the progress and prosperity in recent times of the greater industries of this country can be traced, if not entirely, at least in a large measure, to some new discovery or application of chemical or mechanical science.

The discoveries of the chemist which led to the recent development of our mineral oil trade, of the manufacture of coal tar dyes, with its allied printing and dyeing industries, of our alkali, our sugar, and our steel works, will occur to your minds as testifying to the truth of this observation.

Shipping, in common with the other great industries of the country, has shared in the benefits conferred on trade by the achievements of scientific men.

It is mainly owing to improvements in the material, the structure, and the machinery of our ships that this country stands foremost among the nations in its mercantile marine.

The tonnage of the British Empire reached, at the close of 1881, the enormous figure of 8,575,560 tons—a figure only some two millions less than the tonnage of all the other maritime nations put together; that of the United Kingdom alone was 6,641,267 tons, to which about half-a-million tons has been added in 1882. But the magnitude of the nation's shipping is very imperfectly expressed by these figures; the greatly-increased power for work of modern vessels has to be taken into account in forming a conception of its greatness and of its progress.

The changes that have taken place in the course of time in the form and structure of ships are very striking, and yet it will be seen, when ancient and modern ships are compared, that there are still points of close resemblance between them, and excellences in ancient ships that we continue to copy.

You will understand, however, that we can only to-night give a passing glance at some of the more prominent features of this great subject.

Forms of Ancient Ships.—I have tried to figure on these sheets* that are suspended on the walls some of the earliest types of vessels of which we have any record in ancient history. I don't think there is higher authority than a poet's dream for the first rough sketch that may be described as the dawn of shipping. But if the early races of mankind needed any hint from the lower creation in the formation of vessels, I can imagine that the argonaut and the squirrel might be suggestive to them.

The coracle which is rudely figured here, borne on the back of one of our barbarian ancestors, dates back as far as the history of our own primitive countrymen can be traced, and in shape is not

* Diagrams were shown exhibiting the various forms of ships.

unlike a marine shell. It was made of skins, stretched over a frame of wood or wicker work. With boats of this structure, but larger, our hardy forefathers navigated our shores, crossed to Ireland, and occasionally to Gaul.

It has been remarked as a singular fact, that the Indians of North America, as well as the early inhabitants of Europe, were also known to have made and used similar boats; and what is even more remarkable is, that the coracle may still be seen for sale in the windows of our rubber manufacturers, but made on scientific principles, inflated rubber taking the place of skins.

Inflated skins made to sustain a swimmer, and similar boats drawn by a swimmer, as shown in the early Nineveh sculptures, would be the corresponding invention of a race living in an inland country of warmer temperature, and with only river navigation.

As warlike instincts developed, the craft used for transport increased in size,, and had improved propelling power, the plain paddle used directly in the hand giving place to the more scientific oar used as a lever.

The ambition to build ships of vast dimensions, with which we are familiar, is a very ancient weakness. As far back as the year 220 B.C., the great galley of Ptolemy Philopator was built. This vessel, of which a sketch is on the wall, is supposed to have been about 420 feet long, and 57 feet broad, and to have had, when fully manned, about 4,000 rowers. Such vessels as these were, however, too cumbrous for use, and were intended rather for show on great occasions.

The idea of the "ram," which has been adopted in our modern war vessels, had its origin in these early ships of war.

The use of sails as a means of propulsion was understood at a very early period in the Mediterranean, but for centuries it seems to have been confined to single-masted vessels having a single sail, square in form, and requiring, when set, a fair wind, well astern. The vessels by which Cæsar transported his troops, when he invaded Britain, 55 and 54 B.C., were probably, the larger of them, vessels of this kind; the most considerable may have been about 100 tons register, flat-bottomed, and of light draught of water. The fleet also contained numerous vessels of smaller size, barges, and war galleys.

The discovery, late in the thirteenth century, of the mariner's compass, gave new life to navigation. Oversea voyages could now be undertaken with confidence, and ships adapted to such service

came to be built. A drawing exists of a Genoese vessel of the year 1542, having three masts, and rigged very like modern ships.

In our own country we had made considerable progress in the construction of ships, particularly in war craft. The *Galleasse*, of which this is a drawing, is a formidable vessel of her kind, armed with cannon, and propelled by many rowers, and having a powerful ram in front, similar to that in the ancient war galley built 1,700 years earlier. This *Galleasse* was one of the vessels built to defend our coasts in the time of Henry the Eighth (1546).

But the *Great Harry*, built by his predecessor, Henry the Seventh, is a much more imposing vessel, and in its time helped "to frighten our enemies." She was said to have cost the nation £14,000; the cost of a modern man-of-war is said to approach £600,000.

Towards the end of the fourteenth and early in the fifteenth centuries, good sea-going craft combining the fore-and-aft and square-sail rigs were common—vessels of about 200 tons burden, that could beat to windward and keep the seas in all weathers.

In one of these, named the *W. Matthew*, of Bristol, Sebastiano Cabot, an English-born Venetian, in 1497 discovered Newfoundland. The discoveries of America by Columbus, 1492, and the voyages about the same period by Vasco de Gamma to Africa and India, round the Cape of Good Hope, gave a great impetus to shipping adventure, and to improvement in shipbuilding, in which the British, Spanish, Portuguese, and Dutch were all competitors.

The Dutch, early in the seventeenth century, claimed the mastery of the seas, and overawed the British. Our merchant traders had much difficulty in establishing themselves in the east. It is recorded that out of eighty-six ships which were despatched to India between 1600 and 1616, by the company of traders known as the English East India Company, to whose enterprise England owes its India Empire, eleven were surprised and seized by the Dutch. The kind of ship with which the Dutch carried on their trade and maintained their supremacy is figured in this drawing, and an able-looking craft she is.

But the British East Indiaman, of which this is a drawing, followed, and speedily asserted her superiority.

The material of which vessels, up till this time and down to a very recent period, were constructed, was wood, fastened together with bolts of wood, iron, and copper.

The ravages of marine boring worms were prevented by covering the bottoms with metallic sheathing. Lead in very early times was used, later copper was employed, and latterly and still an alloy of copper and tin, chemical science having shown that this composition, called yellow metal, was well adapted for the purpose. By the slow formation of oxide of copper on its surface, marine grasses were prevented from adhering, and the boring worm, with which most seas, but specially tropical, abound, could not penetrate the metal.

The marine animals which foul ships' bottoms and retard their progress are different from the boring worm, the teredo. They are various forms of *balanus* and *barnacles.*

Modern Ships.—The use of iron as a building material, together with the steam-engine as a propelling power, brought about enormous changes in the size and structure of ships.

The common use of iron for the frames and plates of ships belongs to the last thirty-five years, but we have evidence that it was used in the construction of canal boats as early as the year 1818. I have here the model of what I believe to be the first iron vessel built in this country. The *Vulcan* was built in 1818 in Glasgow, and was used on the Forth and Clyde Canal. She took about ten months to build, was 65 feet long, 11 feet broad, and the same depth, and carried 150 passengers with their baggage on a draught of 4 feet. It is interesting to contrast her model with one of the modern-sized iron or steel steamers. You have here (pointing to models), placed side by side, models made to the same scale, $\frac{1}{4}$ of an inch to the foot.

As the Clyde district was foremost in the use of iron as a ship-building material, so also was it first in the successful application of steam for the propulsion of passenger vessels. I do not refer here to the experimental stage of steam propulsion, in which Miller, Taylor, and Symington were engaged, but to the part Henry Bell took in it when he placed the steamer *Comet* on the Clyde as a passenger steamer in the year 1812, and so introduced steam navigation into Britain.

The *Comet* was 40 feet long, $10\frac{1}{2}$ broad, and of 25 tons register. She was built by John & Charles Wood of Port-Glasgow, and engined by Anderson & Campbell of this city. Other steamers speedily followed—James Watt's firm, Bolton & Watt, becoming famous as ship engineers.

We are all so familiar with ships in their various stages of

construction, that we are apt to overlook the wonderful fitness of their parts to the purposes which they are meant to serve. Confining our attention for a moment to iron as the material of which they are built, we shall see, if we are observant, that the forms given to the metal are carefully calculated to give the required strength to the structure with the least possible weight of material.

The angle-iron, of which the frames are formed, and the bulb T iron used for the beams, are very wonderful examples of lightness combined with strength in the directions of the strains to which they are to be subjected. Besides this, they are singularly convenient forms for the attachment of the parts usually united to them. The angle-iron is doubled in its rigidity by placing two together, as is commonly done, and the free leaf of each gives easy and secure attachment to the outside plating and the inner ceiling of the ship. The angle-iron also is easy of manufacture at the works, and of manipulation in the building yard.

The plates which enter most largely into the structure, besides forming an outer watertight skin, are variously distributed with surpassing skill, so as to give their greatest strength in the line of the strains. Some of our more eminent shipbuilders, by means of their scientific staff, take great pains to calculate and to provide against the strains that each separate part of the structure is required to bear under the varying conditions of loading and motion when at sea; and to the calculations of some of these scientific men do we owe several of the recent important improvements that have been made in shipbuilding. Prominent among these is the great firm of William Denny & Brothers, Dumbarton, who, to the ordinary equipment of a shipbuilding and engineering work, have added a scientific staff, with Mr. William Denny as its directing head. This scientific department is possessed of appliances for testing the qualities of materials of every kind, and will shortly have an experimental tank of vast dimensions wherein to conduct experiments for determining the best forms of ships for purposes of commerce. Great results will doubtless flow from these investigations. The name of Mr. William Denny is already associated with important improvements in ship structure. Although the bracket system of double bottoms, now so common, had its origin in the yard of Austin & Hunter, Sunderland, aided by some of Lloyd's experienced men, the system was taken up with such intelligence and energy by Mr. Denny that he has come to be identified with it. To him also, I believe, we are greatly indebted

for the practice, as part of the regular work of the advanced shipbuilder, of making progressive trials of ships to determine the power expended at various speeds. The data thus obtained, when analysed and classified, enable the shipbuilder to predict the speed and consumption of fuel of new vessels.

The accuracy with which a ship's speed, and coal consumption, and capacity, and stability, and draft of water when laden, can all be foretold before she has been built is perfectly wonderful. On these points there need now be no uncertainty, and numerous examples of this, drawn from the experience of shipowners, could easily be adduced.

The substitution of steel for iron as the shipbuilding material is a recent outcome of science. The regenerating furnace of Dr. Siemens, and the skill of the chemist, by whose aid the elements of steel are now easily blended together in due proportions, have enabled the manufacture of this article on a large scale to be carried on under conditions that at once secure a uniform quality in the metal, and its production at a moderate price.

A couple of years ago it would have interested you to examine the strength and pliability of this metal, but now it is so common as to have lost its novelty. But some of you may yet like to see how steel may be bent cold without breaking, and the recollection of this may lend confidence to you in the strength of the ship, when you are travelling by sea in a Clyde-built steel steamer.

The samples of steel which I show you were taken from the plates used in the building of the first steel steamer—the *Buenos Ayrean*—built for the Atlantic trade, and which it fell to my lot to have contracted for. She was built by Messrs. Denny of Dumbarton. The steel was manufactured by the Steel Company of Scotland.

Engines of Ships.—Passing from the hull of the ship to the engines, let us look for a moment at what science has done for us in the engine department. Here a progress, more striking even than anything we have yet pointed to, may be marked.

The non-condensing indirect-acting engine of the early inventors has given place to the direct-acting condensing engine; the single expansion to the compound, for which we are mainly indebted to Randolph, Elder, & Co.; and recently Mr. Kirk, of Robert Napier & Sons, has shown that a triple expansion of steam is at once possible and economical. The ordinary jet condenser has been displaced by the improved surface condenser, by means of

which the condensed steam is returned as fresh water to the boiler, effecting a great economy in fuel, and the low pressure of the old-fashioned boiler is exchanged for the high pressure of the modern. Engines that in olden times wrought with steam at a pressure of 20 or 25 lbs., now work at 80 or 90 on the square inch. All these advances have had for their end the obtainment of power at reduced cost, and are the fruits of scientific labour. It would occupy too much time to dwell on details, many of which of the broader and more important class will suggest themselves to your own minds; but it may be interesting to glance, in passing, at one or two of the less prominent, and yet most interesting examples of scientific appliance in the engine and boiler room. The marine governor, contrived to prevent the racing of the engines, is a beautiful application of nature's law of gravitation. There are various kinds in use; that now before you is a combination of the ball and fly-wheel governor and may be studied in the model upon the table.

Preservation of Boilers.—The destruction of boilers by rapid corrosion in parts exposed to galvanic action, has recently been almost perfectly overcome by a new and clever use of zinc and copper within the boilers. We owe the new form of this protector to one of the members of the Philosophical Society, who is well-known to you. I refer to Mr. Hannay, associated with Mr. David Johnstone, the Allan Line marine engineer, the latter of whom has given the invention practical effect. The invention has been patented by Mr. Hannay, for the benefit of both gentlemen, and is rapidly going into use. It consists of zinc balls with a rod of copper passing through the centre of the balls to which copper wires are attached. When in use these wires are connected by solder to the parts of the boiler most subject to attack, with the result that the boiler and its tubes are completely protected from pitting. The oxygen, which would have combined with the iron or steel, is taken up by the zinc, and this, owing to its ball form, decays slowly, so that its preservative action continues through a whole voyage. One of the balls, with its copper core and connections, is shown upon the table, and one that has served its purpose, and is considerably decayed, is also exhibited. Mr. Hannay has furnished me with a most interesting description of his invention, and of the process of reasoning by which he arrived at it. It is too long to read, but the following extract, descriptive of the finished invention, will interest you.

Hannay's Electrogen.—"By the use of this simple apparatus, the internal shell of the boiler is made the negative electrode of a galvanic couple, and the evolution of hydrogen, which takes place at the surface of the iron, renders corrosion impossible. The protection is as thorough when the boiler is cold as when in use, so that a boiler may be left full of water for any period without fear of rusting. The apparatus is very simple, and can be applied by any one. The zinc sphere is hung in any convenient manner in the water in the boiler, and the wires attached to it are soldered to any part of the shell or tubes. When any part, such as the furnaces, shows decay, the application of a wire of the Electrogen to the part will immediately arrest corrosion. Tubes which were already far gone, and would have required immediate renewal, have by this apparatus been preserved in use. When scale gathers on the iron the hydrogen evolved by the use of the Electrogen causes it to blister and peel off before it becomes thick enough to be deleterious, so that this apparatus keeps the boiler in thorough order. Its low price renders it the cheapest protective yet devised. An experiment to show the action of the Electrogen may be made in the following manner:—A glass vessel, such as a large tumbler, is two-thirds filled with hydrochloric acid (spirit of salt), and two clean rods, one of iron and the other of zinc, are placed in it. Both, if kept apart, will rapidly dissolve, with brisk evolution of hydrogen. Bring now the two rods into contact at the upper ends, and it will be seen that the evolution of gas from the zinc rod will instantly cease, while that from the iron rod will be as brisk, or brisker, than before. But it will be found that the zinc rod is being rapidly dissolved, while the iron rod (from which the gas is coming) remains perfectly unacted upon as long as any zinc remains. This illustrates both the protection of the iron in an acid liquid, and the evolution of hydrogen, which throws off the scale."

Preservation of Propeller Blades.—Another recent application of the same idea is worthy of mention, and is the invention of Mr. Johnstone. It is well known that propeller blades corrode with amazing rapidity at the back part of the blade near the point, and this corrosion limits the life of an iron or steel blade to a very short period. Mr. Johnstone has contrived, by means of a revolving emery wheel, loosely hung, to polish rapidly, and at the cost of a few hours' labour, the ends of his blades to brightness, and thereafter they are easily coated with block tin, and so protected

from the corrosive action to which they are exposed when in rapid motion. This invention, at present on its trial, bids fair to be a success.

Use of Lignum Vitæ.—One of the simpler, but to me most attractive things in the moving parts of the machinery, is the use of lignum vitæ and of white metal in bushes. I think it was to Penn that we owe the happy thought that "wood" lignum vitæ would be found to wear longer than metal under water in the stern bush in which the propeller shaft revolves. Nothing has yet been discovered to equal lignum vitæ for this purpose; and I saw recently in the works of D. & W. Henderson an improved application of it to rudders. If it succeeds we shall hear no more of the rapid decay of pintles and gudgeons of rudders in ships. The rudder is hung by rings fitting into recesses like those of a thrust block, and placed high above water, for easy access and repair, and the pintles, carefully covered with brass, move under water in lignum vitæ bushes. My only fear is that the point of junction between the brass and iron may be subject to rapid decay from galvanic action.

I need not refer to white metal beyond remarking the fact that a metal so soft that it can almost be scratched with the finger nail is now found to be the best and most enduring material to support the friction of the crank pins and other large moving surfaces in marine engines. The process of reasoning by which this fact was reached must take a very high place in mechanical science.

Use of Steam Power in Loading.—The use of steam power in the minor operations of a ship deserves a passing notice. For many years engines were started by hand, now a donkey engine does the work. All hands in olden times used to be called to the pumps in an emergency; but in iron ships leakage seldom occurs, and when it does, the donkey engine or the main engine does the work. The ship that formerly required four men at the wheel to steer is now steered by steam, the wheel being so easily moved that the finger of a child could do it. Sail is set, cargo loaded and discharged, anchor lifted, and even food is cooked by steam. As a proof of the extraordinary expedition with which cargo can be discharged and loaded on board a well-contrived ship, I may mention that as much as 7,000 tons of cargo and coals have been discharged and loaded at Glasgow in the steel steamer I have alluded to in the short space of four days, working, of course, continuously.

Steam Injector.—Another interesting application of steam has attracted notice. I refer to the *injector*, or *inspirator*, as it is sometimes called, by means of which water is injected into a boiler against the steam pressure of the boiler, and this by the direct action of steam taken from the boiler into which the water is forced.* It is important that questions concerning steam be speedily settled, for we are told that we are soon to see the steam-engine only in our museums, exhibited as a curiosity, the work of a past age, the conversion of water into steam having proved a roundabout way of obtaining expansive power, and a waste of fuel. The new motive power, we are told, is to be gas, produced directly from the coal, and expanded on the spot in a suitable engine, some modification of the existing gas engine. I hope, for the sake of shipowners who have invested their means in steamers, that the change may come by slow degrees, giving time for a gradual transformation of the vessels. I have not referred to the electric light, but it also, as you know, has its place on board ship.

Leaving the subject of the hull and engines of vessels, I shall briefly refer to some of the applications of science in connection with their navigation.

Sir W. Thomson's Compass.—Foremost among the more modern

* I believe the principle of this inspirator was some years ago explained before this Society; and, if I understand what was then said, it was that the steam which forced on the column of water was applied to a greater area of surface than that which met the resistance at the point of entrance into the boiler—that, in short, the stream of water was like a wedge, the force which drove it forward being applied to the thick end while the thin end entered. Before I had heard of that explanation I had been examining the action of the injector, and trying with my imperfect knowledge to understand its seeming impossibility, and the conclusion at which I arrived was, that the steam pressure upon the injected column of water was augmented by the atmospheric pressure on this column, *that* pressure which causes the feed water to rise from its tank and fill the vacuum produced within the body of the injector; and these combined pressures—that of the steam acting on the column of water, and the atmospheric pressure also acting thereon—overcame the single pressure of the steam within the boiler, and so forced in the water. My idea still is that this explanation is the right one, and that it had escaped the observation of the inventor. It is a bold thing for me to hold an opinion upon such a question different from that of experts; but I mention the matter in the hope that some day we may have a short demonstration from some of our many skilled members who hold the contrary opinion, that the first-named explanation is the correct one.

examples of applied science, I would make mention of the compass and sounding machine of Sir William Thomson.

Happily for the present age, Sir William Thomson has devoted some of his energies to the solution of problems affecting everyday work and life. The service he has rendered to electric science has been largely instrumental in bringing the most widely separated places within speaking distance of one another, transforming the whole system of business operations throughout the world. The changes in the methods of commerce that have resulted from the use of trans-ocean cables may be judged from the fact that much of to-morrow's business in America, India, Australia, and New Zealand, has been ordered and regulated from British counting-houses to-day.

The compass and sounding machine which Sir William has given to ships, although apparently insignificant, being simply improvements upon previously existing compasses and machines, are in reality such vast improvements as to take rank among the highest scientific inventions.*

I recollect Sir William's earliest communications to this Society of the result of his experiments with the small needle magnets that move his compass card. He had, before experimenting, reasoned that the disturbance to which all compasses were subject, and which, in iron ships, rendered them untrustworthy, were greatly aggravated in the old-fashioned compass by the mass of the needle, and his experiments, extending over three years, proved the truth of his reasoning.

He showed that the weight of the needles and card of the ordinary compass speedily blunted the centre point on which the card moved, and retarded its motion. He further showed that the large size of these needles required a correspondingly large power in the magnets, and in the boxes of soft iron chain which in iron ships had to be placed near them to correct their errors of deviation, arising from the attractive influence of the ship's hull; and further, that these correctors, while only partially effecting their purpose, destroyed in a great degree the sensibility of the needles. Such compasses were often steady, because they turned with the ship, instead of pointing north when the direction of the vessel's head was changed.

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* Specimens of the most recent form of both the compass and the sounding machine were exhibited.

The compass which resulted from Sir William's researches is marvellously perfect in all its parts. The outer edge of the card is supported on a thin rim of aluminum, the inner parts on thirty-two silk threads stretched from the rim to a small central boss of aluminum. This boss, which has a hole in the centre, rests on the projecting lip of a small aluminum inverted cup, mounted with a sapphire cap, which rests on a fixed iridium point. The needles are eight in number, exceedingly small—two or three inches each—placed side by side, a little apart, fixed on two parallel silk threads which are nicely attached to the aluminum rim. The whole weight of the compass card of 10 inches diameter, with its needles, is only 190 grains. This extreme lightness reduces friction to a minimum, and, owing to the distribution of its weight, the vibrational period of the card is longer than that of the ordinary compass. As a consequence of this, and of an ingenious contrivance recently added for suspending the compass so as to prevent tremor, the tendency which belongs to compasses generally to take an oscillating motion, when the ship is moving in a sea way, is destroyed, and thus the compass preserves its steadiness under conditions which would render the ordinary compass unsteady and unreliable.

The small size of the needles and the means provided by Sir William—the result of careful calculation—to perfectly correct the disturbances caused by the attractive force of the ship, admit of the compass being made absolutely correct at the time and place of adjustment, and to remain perfectly sensitive to every change of position of the ship's head. The advantages of these conditions to the navigator are very great indeed.

It would be wrong to expect that this compass, once corrected, will continue to point true to the north in the same vessel in all latitudes. What it promises and fulfils with absolute certainty is this, that it will retain its power and inclination constantly and readily to point towards the north, but it will also continue to be subject to every new disturbing influence that may arise, and on these occasions will with equal certainty tell the observing mariner that there is a disturbing influence at work calling for vigilance and care.

After crucial tests the compass of Sir William has been adopted in the Royal Navy, as well as in that of France, and its value as a steering compass was experienced in the recent naval action at Alexandria. It has been told that while other compasses were

rendered almost useless from oscillation produced by the discharge of the heavy guns, this compass remained unaffected, even during the continuous firing of the 80-ton guns, and, as a steering compass, was found perfectly reliable throughout the whole action.

It will be in your recollection that a number of the ships were kept moving about while engaging the forts, and so escaped injury from the shot of the enemy. Doubtless, when the full history of the engagement is recorded, it will be found that the possibility of safely performing these evolutions in the limited space to which the vessels were necessarily confined, was in no small degree owing to the steadiness and accuracy of their compasses, which enabled the vessels to be steered and kept in their courses, so as to avoid collisions and grounding during the engagement. If my conjecture be true—and it is not without some foundation—then these compasses of Sir William Thomson will claim no inconsiderable share in the honours of the fight.

Sir W. Thomson's Sounding Machine.—The sounding machine is a fit companion of the compass. The object sought in it is to enable soundings to be taken while a ship is in motion, even at full speed, and this it completely accomplishes.

The "sounding weight" is a cast iron rod, 22 lbs. weight; this carries with it a brass chamber to receive a glass tube, open at the lower end, and closed at the upper. The inside of the tube is coated with a preparation of chromate of silver, a solution sensitive to the action of salt water. The line is made of pianoforte wire, capable of supporting a weight of 240 lbs. without breaking, and yet so fine that it gives little or no frictional resistance in the water, either in its descent to the bottom, or when being drawn on board. The line is wound upon a reel, fitted with a self-acting brake, so contrived that when the weight touches bottom the revolution of the reel stops, and the line is ready to be hauled on board. A dial fixed upon the reel shows how much line has gone out, and approximately, yet with considerable accuracy, the depth of the sounding, allowance being made for the angle from the taffrail of the ship to the bottom.

But the actual sounding is found when the glass tube comes up; as it descended the water rose in the tube, recording on the sensitive inner surface the height to which it ascended—this height is determined by the depth of the water through which the tube has passed, the air within the tube regulates the height the water may rise in it. Each fathom of water displaces, by upward compression,

a portion of the air within the tube, and so the amount of compression being shown on the tube, the number of fathoms of depth of water may be measured. For this purpose a scale is provided to which the tube is applied, and which shows the exact value in fathoms of the section of the tube that has been discoloured by the salt water.

I hope I have by this description succeeded in making it plain to you. I have seen this machine in use at sea with the vessel going full speed, and can testify to its sufficiency. I should add that the steel sounding wire is preserved from rusting by placing it in lime water when not at use.

By the guidance of the compass and the sounding machine which I have been describing, I have known this season of a steamer being safely navigated through a channel abounding with dangers—neither sun nor shore, although the latter was near, being seen for three whole days.

Use of Sextant.—But another and most important scientific aid to the navigator is the sextant, an instrument for measuring the height of the sun or other heavenly body above the horizon. The instrument is furnished with two small mirrors, one fixed, the other movable, the latter being attached to a movable limb. The mirrors are so placed that when an observer looks through the eye-glass also attached to it towards an object in the heavens, the object is seen reflected from the movable upon the fixed mirror, and in its actual position; the limb to which the movable mirror is fixed is then moved along a graduated scale (thus changing the position of this mirror) until the reflected image of the object is brought down to the horizon, the extent to which the limb has been moved to effect this change is read off upon the graduated scale, and is the height, expressed in degrees, of the heavenly body above the horizon.

A chronometer, with which all ships are provided, enables the observer to fix the exact time at Greenwich at which this altitude of the heavenly body was observed, and from these data, the mariner is able, with the assistance of certain tables and simple methods of calculation, in which he is instructed, to determine with absolute accuracy the ship's position, and to lay it down upon his chart.

How Nautical Observations are taken.—For the benefit of those present who have not given any attention to this subject, I will endeavour, in a popular way, to explain the principle upon which the observations of the mariner proceed.

The globe, and the chart, which is an expansion of the globe on a flat surface, *are*, as you know, marked with lines of latitude and longitude.

The lines of latitude run east and west, parallel to the equator; those of longitude run north and south, crossing those of latitude, and converging to the poles. The *latitude* of a place, or a position at sea, is its distance, expressed in degrees north or south of the equator. Its *longitude* is its distance, east or west, from a line passing through the Observatory at Greenwich.

You will understand that if we can say that a ship is upon a certain line of latitude and a certain line of longitude, we fix one special point upon the globe or chart at which she is, being the point at which these two lines meet.

The sailor, then, has to find his *latitude*, and he proceeds to do it by measuring, by means of his sextant, the sun's meridian altitude.

If we imagine a line to pass through the centre of the earth from pole to pole, and to continue into the heavens until it reached the pole star, and if, in imagination, one could stand at the north pole, he would perceive that star to be in the zenith, right overhead.

Then, if we imagine a person to be standing at the equatorial line and looking northward, the pole star will appear to him to be upon the horizon; and if he looked up he would see, right overhead, some other star which would correspond, in his case, to the pole star in the case of the man we have imagined standing at the north pole.

Now, if the person we have placed standing at the equator walk one degree north, the pole star, which was on the horizon when he stood at the equator, will appear to be one degree above the horizon, and the star which was overhead will appear to have sunk one degree backwards.

If he advance two degrees north, the pole star will appear to have risen two degrees, and so on till, when he has reached the pole, it will be right overhead, which would be 90 degrees from the equator.

It follows from this that if the navigator, standing upon the deck of his vessel, can get a sight of the pole star, and can measure the height it is above the horizon, making due allowance for the distance which it is known to be away from the true north, he has an accurate measurement in degrees of the distance he is north of the equator.

The observation for *longitude* is differently made, and its principle is as follows:—

The earth revolves round its axis in 24 hours, and gives the sun the appearance of travelling once round the earth in that time, from east to west; and, as there are 360 degrees in the circle of the earth, the sun will seem to pass over 360 degrees of longitude in 24 hours, 180 in 12 hours, 90 in 6 hours, 45 in 3 hours, and 1 in 4 minutes.

The chronometer, of which I have spoken, is an accurate time-keeper and is set to Greenwich time, which means that at 12 noon the sun had reached its meridian altitude at Greenwich.

Now, if a navigator were finding that the sun had reached its meridian altitude at his ship at a time when the chronometer showed the hour to be 3 o'clock in the afternoon at Greenwich, it would follow that the ship's time was 3 hours later than Greenwich, and, as we have seen that 3 hours

represent 45 degrees, and the sun seems travelling westwards, it follows that the ship is 45 degrees west of Greenwich; and thus, by two observations, he has ascertained his position.

For simplicity I have taken two different kinds of observation, but obviously both cannot be taken simultaneously, as the sun and star are not visible at the same time.

In practice, the navigator ascertains the apparent time at ship at 8 o'clock in the morning, and for latitude he takes the sun's meridian altitude, and he calculates from these observations his ship's position.

It is wonderful to see the degree of accuracy with which a good observer can fix his ship's position, and guide her course. Not long ago I was on an ocean steamer bound for St. John's, Newfoundland. The entrance to the harbour is very narrow, so narrow that a chain used occasionally to be stretched across it to bar the entrance; it is called "the hole in the wall." No observation had been got for about thirty-six hours, but the fog which prevented it having lifted, land was seen about ten miles off. By-and-by it was identified, and, to the delight of the passengers, it was perceived that the ship had all day been steering straight for the opening of the harbour, and did not require to alter her course. An experienced voyager, a military officer, spoke of this nautical feat as "*a shot fired from Cape Clear which struck the bull's eye at Newfoundland.*"

Is the Sailing Ship to go?—The question is sometimes asked, "Is the sailing ship doomed to extinction?" According to many its days were long ago numbered, and the yearly diminishing tonnage of sailing ships encouraged this belief; but at the close of 1881 the tonnage of British sailing ships exceeded that of steamers by about 640,000 tons, and at the end of 1882, while steamers are rapidly increasing, they have only come abreast of the sailing tonnage. The sailing ship has always been the pioneer of the steamer. In certain of the old and long-established trades it has been wholly displaced by the steamer, in others partially; but wherever a new trade is opened, and in old, where long distances have to be traversed and cereal produce or raw material has to be carried, the sailing ship still finds full and profitable employment. In many trades such cargoes cannot afford to pay the higher rate of freight that steamers demand in return for swifter delivery. The sailing ship carries more largely to her tonnage than the steamer, having no machinery nor fuel to take up her room. She is run more cheaply and can subsist on lower earnings, having less money value to insure, and no outlay in coals and engine work. Fuel in some trades costs as high as 50s. per ton. She does not depreciate so rapidly as the steamer, for an old, well-kept ship compares favourably with a new, while the old steamer, as an earning machine, is greatly inferior to the modern; and thus, as new trades continue

year by year to open up, so year by year fresh additions are made to the country's sailing fleet, and the size and style of ship go on improving. It has, therefore, yet a good long life before it.

A contrast between a modern and an old-fashioned clipper is shown upon the table. The law of the survival of the fittest has in late years produced, and is constantly producing, changes both in the form and proportions of steam ships.

The gracefully-curved stem and handsome figurehead, with elegant carving at stem and stern to match, and the bowsprit, are all abolished in steamers. The form of the hull has also undergone changes, with a view to give the greatest carrying space within the enclosing structure. The shipowner is not now so ready to consider, when building a vessel, the lines that are pleasing to the eye, as he is those that rule her carrying capacity, strength, and sea-going qualities. No rule of general application exists to determine the best proportions of vessels, and hence we find that scarcely any two ships are alike. Some time ago the aim was to make vessels long and narrow, under the impression that relatively to their displacement such vessels were most easily propelled. But now the belief has gained ground that short and broad ships are quite as easily propelled as the other, and are preferable for other reasons, and vessels of this description are growing common. How far this change is to proceed, it is hard to predict; but already merchant steamers have been changed from being 11 times longer than they were broad to 7½ times. This is a very striking change when reduced to actual dimensions. For example, if the *Aurania*, recently launched for the Cunard Line, were 11 times longer than she is broad, she would be 142 feet longer than she is.

Another question is sometimes put, "Are masts and sails in steamers to disappear?" Already these have been greatly reduced in size, and only sufficient is retained to enable the ship, if disabled in the engines, to make her way to port under sail.

The twin-screw now being introduced in oversea merchant steamers, if found to be a commercial success, as it promises to be, must speedily come into use for the larger class of new steamers. The propelling power being divided into two separate and complete engines, the parts of each are comparatively light, and therefore easy to overhaul, and being small, the castings and forgings forming them are more certain to be sound. Further, the division of the propelling power into two such engines is bound to lessen by at least 50 per cent. the risk of disablement from break-down, and

to this extent the need of the vessel being provided with sails. As a result of this, masts may come to be made telescopic.

It will, however, take years of familiarity with safety before the shipowner will desire, or the legislature sanction, the entire abolition of sails in the outfit of steamers. No oversea vessel can obtain a government certificate giving freedom to carry passengers unless she be provided with a proper outfit of masts and sails.

II. Influence of Legislation upon Shipping.

Effect of Protective Policy.—The power of a legislature to influence shipping for good or for evil is a very serious fact that ought never to be lost sight of in this country, where we are so dependent upon our mercantile marine. Witness the effect upon American shipping of the pernicious shipping laws of the United States. Once the leader in sailing ships of the highest type, and prominent also in steamers, the United States has fallen into the lower ranks as a maritime country. Her oversea tonnage, which in 1860 amounted to 2,546,237 tons, stood in 1880 at 1,352,810, of which only 146,604 tons were steam, while other nations were progressing. This is wholly due to her protective policy. Unable to compete with Britain in the building of iron ships, she has, notwithstanding, forbidden vessels not built in the United States to be owned and registered there; and she has imposed duties on foreign iron that prevent her own builders constructing ships cheaply. If the United States had not also prevented foreign-owned ships from being employed in her coasting trade, and had not included in that trade her trade between California and her Atlantic seaboard, I verily believe that scarcely any shipping would have been preserved to her.

Awakening to the disastrous consequences of her policy, she is at this moment considering how to remedy it; unable to go the whole length of admitting foreign-built vessels to her registry, she proposes to relieve from duty foreign materials used in the construction of her shipping, but this she inclines to do rather by giving bounties to those who use native material. She must, however, go the whole length of buying her ships in the cheapest market if she is to regain her lost position.

France, resolved to foster her shipping trade, has gone to the opposite extreme. She has encouraged her shipowners either to

build or buy ships at home or abroad, and undertaken, out of the public revenues, to pay to these shipowners a large bounty on every oversea voyage performed by their vessels. As a consequence, our building yards are busy with the construction of vessels for French account, and her merchant navy is rapidly increasing, and is already competing successfully with British ships. It is said that one of their larger lines last year received as bounty over £50,000, being equal to a dividend of 17 per cent. on its capital. The British shipowner asks only a fair field and no favour; but it will be hard to compete against a rival who has a large dividend provided from the nation's purse.

I do not know how far in the end good may come to the French shipowner from this government support upon which he leans. When fleets grow great, as soon they will, the bounty will prove a heavy drain upon the nation, and when withdrawn, I fear it will be like taking the crutches from a cripple—an event that will end in a fall.

The British shipowner is not likely to be able to speak from personal experience of the evils of receiving state bounties; his difficulty has been to get the government restrained from needless interference with his ships and his trade.

Recent Legislation as to Shipping.—The shipping laws have in recent years tended towards increased restriction and interference. The magnitude of the shipping trade, the not infrequent loss of life that arises in it from collisions, founderings, and shipwrecks, attract public attention, and sometimes awaken, as in the late Plimsoll agitation, unreasoning demands for government regulation, to which, although extravagant, the legislature must lend an ear. Sympathy, too, for the sailor in his dangerous calling, and belief in his helplessness when ashore, lead to special legislation on his behalf. All this, though well meant, and to some extent necessary, is not always wise or without its drawbacks. At present the shipping trade is suffering much inconvenience from recent legislation regulating the engagement of sailors, for which a remedy must soon be found.

Unlike other employers of labour, the shipowner is compelled to engage crews for vessels before a government officer, who draws the articles of agreement between the parties. As some compensation for this, the shipowner, previous to the change of the law, could rely upon getting his crew on the sailing day, for if the sailor failed to fulfil his part of the contract, he could be sum-

marily arrested, and upon trial, except when a good reason could be assigned for his failure, he could be imprisoned. The knowledge of this rendered arrest and imprisonment unnecessary. Not more than one man in a thousand during the late years of this state of the law required its enforcement, and ships were manned with their proper complement of selected men, who could be depended upon to steer and keep a good look-out. The well-doing seaman did not object to the law—it had no terror for him. He rather approved of it, for it secured good shipmates, and contributed to his personal safety at sea. But philanthropic theorists discovered in it oppression, as they also believed they did in the system of giving the seamen advance notes. Moved by their importunity, and disregarding the testimony of experienced men, the present Government annulled the law of arrest, and abolished the advance note, and now the shipowner, the sailor, and the country are reaping the fruits of this misguided philanthropy. The sailor's obligation to join his ship is a dead letter; the articles of agreement are only binding on the shipowner. Now, ships from this port (and others elsewhere) go down the river with a large number of their crews awanting, and at the Tail-of-the-Bank such wretched creatures as can be picked up on an hour's notice, ill-clothed, and suffering from want, are put on board to fill the vacant places of selected men. If a shipmaster resorts to the help of a clothes dealer to find men in his emergency, the Government, as happened a few weeks ago at Greenock, prosecute and punish the dealer for unlawfully engaging sailors. Need we wonder if we should find an increasing crop of collisions from bad look-out, and of shipwrecks on our coasts?

When a disaster occurs, the Government institute an inquiry as to its cause. The leading questions put are—"Was the ship seaworthy and not overladen? Was she properly manned and navigated, a proper look-out kept, and soundings taken?" The loading and seaworthiness of the ship are seldom successfully impugned, and the shipowner has an interest in testifying to the efficient manning and management of his vessel, so that her crew defects do not appear; but how can we expect a proper look-out to be maintained by ill-clothed men gathered hastily from the streets? How can such men support the rigours of a winter day at sea, or in the channel standing for hours on a forecastle head? And how can better men be got under existing law?

The advance note in its old form has by law been abolished,

but it still exists, and in a worse form, and advances are now of necessity given where formerly they were unknown.

As to Government surveys and oversight, they should be confined to the narrowest limits consistent with public safety. The Board of Trade Surveyor is not an inventor, and when the engineer or shipbuilder has to use special materials, and to conform to prescribed dimensions of parts in the construction of engines and boilers, in order to satisfy the Board of Trade, the inventive faculty is cramped and improvements rendered difficult of introduction. Further, when surveyors, who are not themselves engaged in trade, are called upon to enforce rules laid down to them from London for the regulation of loading and freeboard, and the determination of seaworthiness, their action may become oppressive, and positively injurious, if not tempered with judgment. A proposal to create boards of reference from the decisions of local surveyors has met with considerable favour, but the evils that may arise before a board of reference has time to act may be very serious indeed.

It will be well in addition to have men of good judgment in the guidance of the work of survey—men in sympathy with trade, and who, having discretion granted to them, and a direction to avoid undue meddling, will know when to interfere and when to forbear.

A change in the constitution of the Courts of Inquiry, or an appeal from the decisions of the Courts, is required to satisfy the trade.

Foreign Trade.—I doubt if this country, and our legislators in particular, are fully alive to the importance of our foreign trade and maritime commerce.

Mr. Gladstone's views on this matter are somewhat difficult to discover. In his Midlothian speeches, when criticising the conduct of the Conservative Government in their efforts to preserve, by means of strongholds and otherwise, the highway to our Indian Empire—an empire upon which a very large part of our maritime commerce depends—he objected to their policy in language that could not be misunderstood; but he has recently shown himself keenly alive to the duty of preserving this highway, and has succeeded in preserving it.

But Lord Derby—a statesman noted for his sagacity—has told us plainly what he thinks on the subject. His view, as given in a carefully-studied speech to the Huddersfield Chamber of Commerce three years ago, is, that the foreign trade of this country

is inconsiderable in comparison with its home trade. His words on this head were —

"Now, as to the next point—the proportionate importance of home and foreign trade—you will not, I am sure, suspect me of indifference to those vast commercial interests which it is the boast of England to have created. But we can only gain by substituting precise statements for vague generalities, and, freely admitting that I was not prepared for the result of statistical inquiry on this point, I am not unreasonable in supposing that many persons may be in the same condition. What, then, is the aggregate of our national income? and in what proportion is it swelled respectively by home industry and foreign trade? I see no reason to doubt that our best statisticians are right when they fix the amount of incomes liable to taxation at an aggregate of not less than £800,000,000. The calculation of those most competent to judge is that the incomes which are liable to taxation, and those which, from their smallness, escape it, about balance one another in aggregate amount. If they are right, you have a gross national income falling little short of £1,500,000,000; but let us call it £1,000,000,000. Now, how much does foreign trade bring in? That is a question which we can answer with a reasonable degree of certainty. Taking the whole value of British exports at £200,000,000, which is a fair average, and deducting the price of the raw material imported from abroad, we have about £140,000,000 as the profit which remains in English hands. That is about one-seventh of the total aggregate income of the community. No doubt it is a large, even an enormous figure, but it scarcely justifies the language which we often hear, as if the home trade were a comparatively trifling matter, and as if the industrial life or death of the nation depends on the keeping up of its exports."

Now, let us see if Lord Derby's figures are fairly comparable, and represent the proportionate value of home and of foreign trade.

The profit in English hands from the foreign trade he deals with is fairly stated (although to-day his figures would require to be enlarged 50 per cent., say to about £300,000,000 instead of £200,000,000), and so also is his estimate of the aggregate income of the community; but does it follow that because they differ in the proportion of one to six that the home trade produces six-sevenths of the nation's income and the foreign one-seventh?

I think not. While the labour bestowed on £60,000,000 worth of raw material raises its export value to £200,000,000, and the direct value of such labour is thus £140,000,000, our national income derived from this source, as it will appear from Income Tax returns, is swelled by a figure enormously greater.

Take a simple illustration, and this will at once appear. A workman gets a piece of imported raw material worth say £60, and in a year he raises its value by his labour to £200, he thus

earns £140, and his Income Tax return, if made, is £140. But assuming that he spends all his earnings in the maintenance of himself and family, his shoemaker, clothier, baker, butcher, schoolmaster, and landlord get the money among them, and in so far as what they give in return is not imported raw material, but the fruit of their labour, or the labour of some one else in the country, the workman's expenditure figures as income in the Income Tax returns of the shoemaker, baker, butcher, &c. Taking as the value of their labour a proportion of the whole sum similar to that of the workman's, £98 of the workman's expenditure will appear in the Income Tax returns of the shoemaker, baker, &c., and now the workman's income of £140 figures in the Income Tax returns at £238.

Apply this method of computation to the larger figures with which Lord Derby deals. Call the workman's pounds millions, and you have at once in this first sequence the profit on the raw material worth £60,000,000 figuring in the Income Tax returns not at £140,000,000, as Lord Derby expresses it, but at £238,000,000. But the figure does not stop here. The shoemaker, tailor, baker, &c., spend their £98 in a similar way to the workman, and in the new sequence, taking a like proportion as the value of labour, their expenditure will figure as income in the Income Tax returns at £68—another £68,000,000 added to the £238,000,000, making £306,000,000; and so on through an extended series, the number of which will be determined by the proportion which the suppliers of the necessaries of life bear to the producers of the wealth which purchases these necessaries. The question of the composition and sources of the national income, as returned for tax, is wide and intricate, and would require for its full elucidation a separate paper. But enough has been said to show how fallacious and misleading are Lord Derby's conclusions; and yet the press accepted them, and many minds during the past wave of dull trade were comforted by his suggestion that the country might prosper although its foreign trade should decay. Happily, foreign trade somewhat revived, and shipping trade revived; the country, in consequence, returned to some prosperity, and the fallacy of Lord Derby's reasoning was not put to the test of experience, else it would have been discovered that the decadence of our foreign trade and maritime commerce, which are linked together in a bond that cannot be severed, was the ruin of the country.

Maritime Commerce.—But let us try to form some idea of the part which shipping plays in the nation's trade. It is common to contrast the nation's property in railways and its property in shipping, and to assume their relative importance in the country's commerce to correspond to their respective capitals. In railways the country has invested over £728,000,000 of money, and the lines exist to represent the expenditure—but it is to be remarked that much of this expenditure is money paid for land, which is simply an exchange operation—I cannot tell how much the nation has expended in shipping property, for it is lost and replaced once every 20 years or less, but we can only at this moment show shipping property representing in value about a seventh part of the railways, say £105,000,000 (almost all of this, however, is created wealth). This estimate I arrive at as follows:—

The sailing fleet at end of 1882 is estimated to stand at 3,548,000 tons, which at £12	= £42,576,000
The steam fleet, 3,543,000 tons, at £15 per ton, ...	= 60,231,000
Plant ashore, say	= 2,193,000
	£105,000,000

(This makes no account of the money invested in docks and harbours.)

But the effective power of shipping in the production of revenue is very much greater than that of railways. While the railways of the kingdom have a total revenue from all sources of about £65,500,000 per annum, the shipping of the country, although representing only a seventh of the railway capital, I estimate earns about £64,000,000.

It is difficult to form a reliable estimate of shipping revenues, but, from data in my possession, I think I am not far wide of the mark if I put the gross annual earnings of sailing ships at £5 10s. per ton, and of steamers at £12 10s. per ton. Taking all classes into account, my data point to a higher average, but I have taken the lower:—

Sailing ships would yield	£19,514,000
And steam	44,287,500
	£63,801,500

Of these revenues, about 75 per cent. will return to this country,

and 25 per cent. remain abroad as the charges of foreign ports. £48,000,000 may thus be taken as the British share of these revenues, of which fully three-fourths, or £36,000,000, will be spent chiefly on labour and home products (sailors alone receive over £12,000,000 of it), and the remaining £12,000,000 in the maintenance of owners, or remain as accumulated wealth to be expended partly in the extension of the nation's shipping. But it is to be observed that the shipping revenues are computed only from and to the seaboard; but their effective value does not terminate there—the railway haulage of imports and exports, and all the labour and cartage connected with their movement, including much passenger traffic, forms part of the service. We know from experience of the inland haulage in America that it nearly equals the ocean freight, and we will not err on the side of excess if we assign to the British a fourth of this proportion, which would represent a sum of £16,000,000.

We have thus revenues directly created by the shipping trade of the country amounting to the vast sum of £80,000,000, of which £64,000,000 remain to this country.

The tonnage built and added to our registry in 1882 was—

Sail, 173,098, valued at £12, ... =	£2,077,176
Steam, 804,480, valued at £17, ... =	13,676,160
About 50,000 tons of steam which have not passed through our registry is estimated to have been built for foreigners, at £17.	850,000
Total, ...	£16,603,336

and, with the exception of the value of such raw imported products, say of timber, iron, and other ores, and cordage fibre, as enter into the manufacture of new materials, everything which enters into the structure of these vessels may be said to be home produced. We are safe, then, to assume that over £15,000,000 of money have been directly distributed among the various industries of the country in the building of the last year's new ships. What proportion these millions of revenue from shipping and shipbuilding form of the estimated income of the nation, as computed from Income Tax returns, it is hard to say, but that the foreign trade and shipping together form a vast proportion of it—possibly two-thirds—I think there is hardly any room to doubt.

We have seen that, as Income Tax returns are reckoned, £140,000,000 of direct earnings from exports might become

£306,000,000 of the country's income ere it passed beyond two sets of hands from those of the primary earner, and the £140,000,000 being derived from £200,000,000 value of exports, £300,000,000 being last year's, would raise the sum 50 per cent., or to £459,000,000.

Unlike the value of exports, the British share of shipping revenues needs no allowances taken from it for raw material. It is a directly-created wealth. In assigning to it and to our export trade that high place which I claim for them in the nation's balance sheet, I would have you consider what are the other actual sources of wealth in the country for which a rival claim can be set up. Except what we owe to agriculture, to fisheries, and to minerals, enhanced by labour, aided by machinery (a portion of the mineral section, it must be remarked, falls under exports and shipping), and the revenues derived from foreign investments of capital, I don't know of any. Such callings as banking, stock-broking, insurance, professional work, shop-keeping, newspaper and other publishing, within the country, although yielding to individuals incomes which figure largely in the Income Tax returns, do not create wealth in the sense in which the others create it. Towards these they stand very much as the commissariat and camp followers stand towards the army in the field. In so far as they contribute at all to the nation's creative wealth, it is as dependents they do it. Extinguish the other sources of wealth, and not one of these could exist or help its neighbour.

The value of our agriculture is great. Some years ago, when land was more valuable than it is now, the gross annual rental of the land of the three kingdoms was estimated at £131,500,000. The value of its produce must be taken to be this rental, *plus* the wages of the farm labourers and the profit of the farmer. But when you consider how few people, comparatively, agriculture, as an industry, gives employment to, its small value to the country, in contrast with that of the industries I have been speaking of, will appear. Much of the acreage is devoted to sheep and deer. A few shepherds and keepers tend these domains. The crop farmers, even on a large scale, need only a small number of men and of maid servants. The rental of the land (which represents the raw material) therefore does not receive much enhancement from labour. I shall not, however, attempt to put a figure upon it in the absence of reliable data.

Nor is the distribution of the money derived from the produce

of the land beneficial to the people in the same degree as that from the other industries. The rental, in so far as it is not taken up by payment of interest to bondholders, is used to maintain in luxury a comparatively small number of landed proprietors and their dependents, who are not producers, and the bondholders in turn are similarly circumstanced.

I have no data concerning fisheries; but they and agriculture would not employ so many as are now engaged in them if the other industries were crippled, and, further, the value of their produce is enhanced by the demand created by the wants of the classes engaged in other industries.

We see also how poverty-stricken are many of the people both in Scotland and Ireland who depend on agriculture and fishing for their livelihood.

The Need of Protection of a Special Kind for our Mercantile Marine.—An enormous proportion of the country's food supplies is brought in by our foreign shipping week by week.

Glasgow alone receives about 10,000 tons a week, and the country at large about 170,000 tons a week all the year round.

Different from former times, these food supplies go directly from our wharves to the consumers. They are not stored as they used to be for later distribution. How serious, then, would a stoppage of our shipping trade become? The interruption of our supplies, even for a period of weeks, would produce famine prices, and speedily positive famine.

The imported raw materials of our manufactures, like our food supplies, are also sent directly from the ships to the place of use for immediate conversion. A cessation of imports would speedily bring great industries to a stand-still, and a disturbance to the outflow of our exports would paralyse vast communities, the consequences of which it is terrible to contemplate.

It behoves the Government, and all public bodies who exercise any control over our commerce, to weigh well these facts, and each in its place to promote that commerce which is the life-blood of the nation. It ought to be imperative upon the Government to remove every hindrance that it at present opposes to the shipping trade. Besides things already noted, which require remedy, there is something to be done in the tonnage laws, to encourage good types of ship. Customs restrictions should be relaxed—as, for example, freedom to work night and day in port without fee for permission, freedom to carry goods coastwise in vessels partially

foreign laden, whether outward or homeward bound, should both be granted. Shipping also should be relieved from those heavy and vexatious fees which are now demanded by the Board of Trade for the services of their officers—all of which being professedly in the public interest, should be at the public charge.

But, above all, in view of our great dependence for our daily bread upon our shipping, it is absolutely necessary that the Government, while it guards our shores and the highway to our colonies by strong posts on the way, should provide powerful and rapid cruisers, numerous and powerful enough to sweep the privateer from the seas, should he ever appear, and to protect our ships at sea from the swift enemies that will be launched against them if we ever find ourselves at war with a great power.

XIII.—*Some Account of the Iron Ore Industry of the North of Spain.*

By JAMES G. JENKINS, M. I. & S., Glasgow.

[Read before the Chemical Section, 18th December, 1882.]

ALTHOUGH the iron ore deposits of the Bilbao district have been known for a very long time, their value to Great Britain may be said to date from about the year 1870.

It may not be out of place at this time to refer to the conditions under which Spanish ore obtained the importance it now possesses.

Cumberland has been called the birth-place of hematite pig-iron. It was from here Bessemer obtained those samples of pure pig-iron, free from phosphorus, &c., that enabled him to carry out his experiments that gave to the world Bessemer steel, and rendered the name of the inventor famous. At the time Bessemer was searching out the truths connected with the manufacture of steel, and when Siemens was carefully working out the process that has been so successfully identified with his name, the great bulk of the ore raised from the rich deposits of hematite in Whitehaven and Furness districts was exported to other iron-making centres—chiefly Scotland, South Wales, and Middlesbro', where it was used as a mixture in smelting the poorer ores of these localities.

The increasing demand for hematite pig-iron, consequent on the success and development of the Bessemer and Siemens' processes, was the means of attracting the attention of capitalists, and Cumberland was the chosen ground for the erection of many iron works whose aim was the conversion of rich deposits already referred to into pig-iron. It will thus be seen, as the demand for ore amongst the local works increased, there was less to spare for other districts, until we find at the present day, with some

exceptions, the great bulk of the hematite ore of both Furness and Whitehaven is smelted on the spot—the demand in brisk times being slightly ahead of the production. I may note here, Spanish ore is being brought into Cumberland at the present time. This is due, however, more to a question of price than a scarcity of ore.

In Scotland the demand for steel, as a constructive material for shipbuilding, &c., was the means of establishing the steel works of Newton, Blochairn, Parkhead, Mossend, and Dalziell, and immediately the attention of Scotch ironmasters was directed to the manufacture of hematite pig-iron.

In Middlesbro', over-production of common iron, added to a dullness of trade, caused an accumulation of stocks, and, in order to relieve themselves, the ironmasters there changed a number of their furnaces on to hematite pig-iron.

In South Wales the necessity for a substitute for Cumberland ore was even greater than in Scotland or Middlesbro'. The exhaustion of many of the fields of ironstone had rendered it absolutely necessary ore should be obtained from somewhere. It was at this time the attention of ironmasters was attracted to the rumours of rich deposits of hematite ore in the Bilbao district.

In the remarks I will have to make in the following description of the Bilbao deposits, it is my desire to be as general as possible. The subject is not one that admits of a purely chemical treatment, whilst the geology of the district has, up to the present time, had little attention paid to it.

The iron ore district may be said to begin above the town of Bilbao, and to extend along the left side of the River Nervion until it reaches the coast at Onton. Don Francisco Uruburu, the Chief Engineer of Mines for the Province, divides the district into 10 groups, viz.:—

1. Minas de Basuri y Arrigorriaga.
2. ,, Begoña.
3. ,, Abando.
4. ,, Gueñes.
5. ,, Baracaldo.
6. ,, Alonsotigui.
7. ,, Galdames.
8. ,, Sommorostro.
9. ,, Soupuerta.
10. ,, Onton.

The mineral found in these various groups is divided into three classes, viz.:—campanil, vena-dulce, and rubio.

With some trifling exceptions, the whole of the campanil supplies are obtained from the Sommorostro, or, more properly speaking, the Triano group—vena-dulce or rubio being the ore of which the other groups are composed. At the present moment the chief centre of interest is the Sommorostro group, as it was from this locality 93 per cent. of last year's shipments were obtained, the three qualities of ore being represented.

Campanil, the ore most sought after, is a hydrated oxide of iron, $Fe_2O + H_2O$, of a more compact nature than vena-dulce, shows a clear crystalline fracture, and is often associated with beautiful crystals of carbonate of lime. The following may be called a characteristic analysis:—

	Wet.	212°
Peroxide of Iron, ...	69·37	79·24
Protoxide ,, ...	—	—
Bisulphide of Iron, ...	·28	·32
Oxide of Manganese, ...	1·50	1·71
Lime, ...	2·72	3·10
Magnesia, ...	·77	·88
Alumina, ...	1·37	1·56
Silica, ...	5·25	6·00
Phosphoric Acid, ...	·04	·05
Sulphuric ,, ...	—	—
Carbonic ,, ...	2·72	3·10
Water (Combined), ...	3·54	4·04
Water (Moisture), ...	12·44	—
	100·00	100·00
Sulphur, Pure, per cent., ...	·14	·17
Phosphorus ,, ...	0·17	0·21
Iron, ,, ...	48·69	55·61

Vena-dulce is also a hydrated oxide of iron, of a dark rich colour, very soft, and easily reduced to a finer state than either campanil or rubio. This ore is often found associated with clay. Vena-dulce is generally found in the wettest places of the mines, or near the surface, therefore requires careful classification, which can only be done when the conditions of weather are favourable. Vena-dulce, or, when literally translated, "soft vein," is the ore which was worked in olden times for making iron direct by the Catalan process, being easily obtained without the aid of gunpowder.

The following is a typical analysis:—

VENA-DULCE.

Peroxide of Iron,	80·500
Oxide of Manganese,	2·320
Sulphuric Acid,	0·065
Phosphoric ,,	0·041
Magnesia,	0·376
Lime,	0·570
Insoluble Residue,	7·849
Carbonic Acid, and Combined Water,	8·280
	100·004
Metallic Iron, per cent,	56·400
Manganese,	1·800
Sulphur,	0·026
Phosphorus,	0·018

The above is from a sample dried at 212°.

As a rule, vena-dulce may be said to contain more metallic iron than campanil or rubio, the percentage of manganese is also slightly higher than in either of these ores. Its softness is the principal objection against it. Being easily crushed during so many handling operations, it frequently arrives in this country in a finer state of division than the ironmaster likes. For this reason alone its use in the Siemens' process has been prohibitive.

Rubio ore, a brown hydrated oxide of iron, different in appearance from either of the ores I have described, exists in by far greater proportion than the others, and is the ore on which the future supply will chiefly depend. Rubio is not quite so rich as campanil in metallic iron; it is generally found associated with or resting on sandstone, and on this account requires careful classification. It is a harder ore than either of its neighbours, bears transport better, and has the redeeming quality of not absorbing so much free water.

The following is a fair average analysis:—

Peroxide of Iron,	71·18	76·96
Bisulphide of Iron,	·09	·10
Oxide of Manganese,	1·83	1·98
Lime,	·74	·80
Magnesia,	·87	·95
Alumina,	2·53	2·74
Silica,	8·62	9·32
Phosphoric Acid,	·036	·039
Sulphuric ,,	Trace.	Trace.
Carbonic ,,	—	—
Water (Combined),	6·79	7·30
Water (Moisture),	7·50	—
	100·186	100·189

Iron, Pure, per cent.,	...	...	...	49·82	53·87
Phosphorus,	,,	...	...	...	0·49	0·53
Sulphur,	,,	...	...	...	·016	·017

The varying percentage of carbonate of lime in campanil, from 2 per cent. up to 10 per cent., is frequently the cause of irregular working in the blast furnace.

Regarding the theory of formation—how such masses were deposited—but little has been written on the subject, the energies of all concerned, both Spanish and English, being concentrated more in the getting of the mineral than in working out speculative problems in geology. Found in the cretaceous measures, and resting on limestones, it is supposed a violent geyser action took place, during which fountains of carbonate of iron were ejected. Geologists find the evidences of the geyser action in "the crystalline texture of the campanil, the beautiful crystals of carbonate of lime that accompany it, in the concrete forms of the rubio, and the quartz crystals which fills its loughs."

Mr. Kendal, in a paper on the Whitehaven deposits of hematite, read some time ago before the North of England Institute of Mining and Mechanical Engineers, shows the Cumberland ores may possibly have been formed from carbonate of iron acting on limestone. It may be expressed by the following chemical formula:—

$$FeO\ 2Co_2 + CaO\ Co_2 = Fe\ Co_2 + 2CaO\ 2Co_2.$$

Laboratory experiments have shown that limestone is soluble in water containing an excess of carbonic acid. From this it is reasoned the limestones found associated with the Spanish ores have in many places been dissolved by the carbonic acid, and carbonate of iron formed, as shown in the above reaction. The subsequent conversion of the carbonate of iron into the peroxide of iron may be expressed by the following:—

$$2FeO\ Co_2 + O = Fe_2O_3 + 2Co_2.$$

It may be a matter of speculation how the iron was originally deposited, but there is little room to doubt that the whole of Bilbao deposits were at one time spathic ore (carbonate of iron), and that their subsequent conversion to peroxide has been accomplished by atmospheric influences. If we examine a piece of spathic ore we find identically the same characteristics as we do in campanil—the same compact nature, the same crystalline form. Calcine a

piece of spathic ore, and the result will be shown, on analysis, to be an ore identical with campanil, only richer in metallic iron, owing to oxidation being more complete; and the water that is chemically combined with the campanil is absent in the calcined ore. The process of calcination may be seen in nature, only under different conditions. Allow a piece of spathic ore to be exposed to atmospheric influences for a time, and you will notice the surface gets slowly oxidized, presenting an appearance exactly corresponding to campanil; or, examine spathic ore, over which water has been allowed to percolate, and you get the same chemical action, with the same results. It is somewhat more difficult to account for the conversion of spathic ore into rubio. A comparison of the analysis of campanil and rubio shows that, whilst carbonate of lime is always present in the former—to a greater or less extent in rubio—it is reduced as low as 0·5 per cent. This can be accounted for by the fact that campanil is always found intimately associated with limestones; whilst rubio, although sometimes found with limestone, is nearly always found resting on a micaceous sandstone. This sandstone has, to a certain extent, entered into the chemical composition of the ore, and we find the low percentage of $CaOCo_2$ is replaced by an increase of siliceous matter. Indeed, some of the poorer classes of rubio ore are simply sandstones largely impregnated with oxide of iron. Don Ramer de Yarza, in an able paper on the geology of the district, although unable to explain why rubio ore presents a different structural appearance to campanil, nevertheless attributes its origin to the same agency. He says—"The quartz crystals which accompany it (rubio), if viewed under a microscope, shows a prodigious number of cells, containing liquid whose characteristics coincide with those Zirkel attributes to those found in water and carbonic acid, since they completely fill the irregular cavities, show great refractory power, and little or no mobility. The bubble which each of those cells contains is perfectly spherical, of very small proportions relatively to its contents, and does not change in volume under changes of temperature." From this, he shows the medium under which those crystals were formed was water, impregnated with carbonic acid—the carbonic acid being obtained from the spathic ore or limestone.

An inspection of the Onton mines goes far to show the relation of spathic ore to rubio. Here we find extensive deposits of rubio ore, at present being worked, separated only by the smallest of

rivulets, and not more than a stone-throw from a very large body of (spathic ore) carbonate of iron. In one case the conversion to brown ore has taken place, whilst, in the other, it would seem as if nature meant it to remain as a testimony of the original condition under which the ore was deposited. In the deposit of spathic ore at Onton, which is 60′·0″ thick, it is singular to notice in the upper 12′·0″ the ore is largely impregnated with argentiferous galena, containing, as it does, 42 ozs. of silver to the ton of lead. Suitable works, under the able direction of Don José MacLennan, are in the course of erection, for the calcination of the spathic ore and the treatment of the silver and lead.

MODE OF WORKING.

The mines are all worked on the open cast system—in other words, simply quarrying the mineral after the overlying *debris* has been removed.

In the mines the writer had charge of it was no uncommon occurrence to have shots 40′·0″ deep in solid ore. Before the powder was placed in the bore-hole, a number of cartridges of dynamite were exploded, forming a chamber in the bottom of the hole something like the shape of a water-bottle. The powder was filled into this chamber until it was found to rise in the bore. The powder was then stopped, carefully tamped, and, in order to avoid the chance of a miss-fire, three fuses were inserted. If the shot worked well, it was no uncommon sight to see 2,000 tons of pure mineral brought down by one blast. Much, however, depends on the judicious selection of the placing of the shot. The ore had simply to be broken up by means of dynamite, selected and loaded into waggons. This brings us to the means of transport, which may be classified as follows:—Railways, wire tramways, inclined planes, bullock carts. Of the first we have the Orconera Iron Ore Co's. Railway, which brought down 728,607 tons during the year 1881; the Franco Belge Railway, 150,561 tons; the Provincial Deputation, which carried 1,161,025 tons; and the Bilbao Iron Ore Co.'s Railway, which carried 441,906 tons.

The excellence of the work done by the Orconera Co., the handling of such large quantities by the Deputation under conditions which must be admitted unfavourable, and the engineering difficulties overcome in the construction of the Galdames Railway,

are the most noteworthy points in connection with the railway means of transport.

Wire Tramways.—This system of transport has been largely made use of, and often with exceedingly good results. In places where the construction of a railway was either impracticable, or would have been attended with great expense, wire tramways have been substituted. The placing of a number of wooden trestles down the side of a hill, at distances according to circumstances, an endless steel rope running over pulleys mounted on the trestles, and a stationary engine at one end, is all that is required. The buckets, which generally consist of barrels sawn in halves, are fixed on the rope by means of a hook or clip. A more detailed description of this system of transport would come in more properly under the Mechanical Section of this Society. The same may be said about inclined planes.

Bullock Carts.—This, the most antiquated of all the means of transport, is still extensively employed—so tenaciously do Spaniards adhere to old manners and customs. To a stranger, standing either at Ortuella or Pucheta, and seeing the long array of bullock carts slowly wending their way to the mineral stations over badly-constructed roads, the sight is an interesting one. There is one advantage this system possesses over any other means of transport in the district, the bullocks are more suited for the climate and the work than either horses or mules—strong and patient. I regret to say they are often subject to the most barbarous treatment from the hands of their drivers.

STATISTICS.

	1878. Tons.	1879. Tons.	1880. Tons.	1881. Tons.
Total Output, ...	1,224,730	1,117,836	2,345,598	2,500,532
Campanil, ...	—	—	—	1,516,051
Rubio and Vena,	—	—	—	1,284,699
				2,800,075

An analysis of these quantities shows the following proportions taken by the undermentioned countries:—

	Per cent.	Per cent.	Per cent.	Per cent.
England, Scotland, ...	74	63·75	72·00	68·75
Holland, ...	8·0	11	12·50	13·50
France, ...	12·0	18·25	10·50	13·50
Belgium, ...	5·0	3·5	3·50	3·50
America, ...	·5	1·5	1·50	·75

It should be noted that, whilst 74 per cent. of the total output of 1878 represents an aggregate of 963,483 tons delivered in England and Scotland, 68¾ per cent. of the total output of 1881 represents a tonnage of 1,713,639, or an increase of 810,156 tons in the short space of three years; in other words, the consumption of Spanish ore in Great Britain has about doubled itself in the time already mentioned.

Coming nearer home, we find Scotland credited with 47,445 tons in 1878, whilst in 1881 the quantity imported had risen to 246,634 tons. These figures are sufficient in themselves to justify this Society in obtaining all the information they can on so important a subject. I may mention the increased imports into England have been generally distributed—South Wales taking the largest share, for reasons already referred to in the beginning of this paper.

How long are the deposits to last? is a question that may naturally be asked, as it is one of importance, not only to Great Britain, but to Europe. No attempt has been made by the Spanish Government, nor by the Provincial Authorities, who have so much benefited by the development of the mines, to prove, by boring or otherwise, the extent of the deposits. Engineers have calculated, from data of their own, the existence of about 160,000,000 tons of ore. This estimate can only be taken as approximate.

There can be no doubt that the consumption of campanil far exceeds the known supply, and, as the floor of the ore has been reached in many of the mines, it is simply a question of a few years when the exhaustion will be complete. A competent authority states the present output of campanil may be maintained for other five years. After that it will dwindle down to comparative insignificance, and in ten years, unless new deposits are found under workable conditions, the supply will have almost entirely ceased.

On the other hand, rubio, which forms by far the greater proportion of the whole deposits, exists in quantities sufficient to supply all known wants for a long time to come, and it is to this mineral we must look for our supplies in the future. Many rubio mines, which—owing to their geographical position and the difficulties attending the transport of the ore—have lain untouched, are now brought within reach of the shipping port. All that this ore requires is care in the mining and classification. Give it this, and it is quite as suitable for the ironmasters' wants as campanil.

It is quite natural steel-makers by the Siemens' process will

prefer using campanil so long as they can get it. I would recommend brown ore to their attention; they can get it larger and rounder than the campanil, owing to its bearing transport better, and in using it they will only accustom themselves to what they must inevitably fall back on or go elsewhere—and that place has yet to be discovered—for fresh deposits of ore similar to campanil.

Iron-making in Spain.

For many years the question of smelting Spanish ores on their own ground had engaged the attention of English capitalists. Previous to the late Carlist war, a company was formed, land purchased at San Nicolas, and the erection of blast furnaces began. The unfortunate civil war above referred to, and which had for the centre of its operations the very heart of the iron ore district, stopped for a time the completion of these works. After peace was restored the works were not proceeded with, for reasons best known to those interested. Ultimately they were purchased by a Spanish nobleman, completed and put in operation, with results that can only be termed gratifying to the lucky purchaser of these works. It may be useful to examine in detail a few of the facts connected with the manufacture of pig-iron at home and abroad.

In Cumberland it requires 36 cwt. of ore to make one ton of pig-iron. Take the cost at 15s. 6d. for ore delivered into works.

	s.	*d.*
36 cwt. at 15s. 6d. per ton, ...	27	10
In the Bilbao district, say 2 tons of ore at 7s. 3s. per ton,	14	6
	13	4

Showing a difference in favour of making pig-iron in Spain of 13s. 4d. per ton of pig-iron in so far as ore is concerned, and this is substantially accurate as regards the other items in the cost of making pig-iron.

The best Durham coke can be shipped either in Tyne or Tees, and taken to Bilbao for a mere fraction more than the railway carriage on the same coke into the Cumberland district—this fractional increase in cost of transit being more than compensated for by using a less quantity per ton of pigs made, owing to the Spanish ores being more easily reduced in the blast furnaces. Limestone is abundant and cheap, and the same remarks apply to labour,

whilst the absence of all trades combinations on the part of the workman removes one of the long-standing difficulties ironmasters have had to fight in this country. Outward freights with pig-iron to continental ports are no dearer than from England, whilst for consumption in Spain a protective duty of about 20s. per ton, places in the hands of the Spanish ironmaster the means of realising a handsome profit. Take, for example, Middlesbro' pig-iron, as being the cheapest, and therefore bought by the copper companies in the South of Spain for precipitating copper from pyrites, as costing 42s. 6d. per ton, add 10s. freight and 20s. duty, bringing the total cost delivered at 72s. 6d. per ton. How different with pig-iron made in the country, its cost not more than 42s. 6d., with say 7s. 6d. freight, to the South of Spain, or 50s. against 72s. 6d.—a difference of 22s. 6d. in favour of Spanish pig. True, it may be said hematite pig is too good for the copper companies. I should suppose the only question they had to consider was price, not quality.

The establishing of iron works in the North of Spain would be of immense benefit in another way. On account of dear freight to this country ironmasters have been compelled to insist on a high standard of quality, and, in order to maintain this, immense quantities of poor ore—say about 40 per cent. metallic iron—have to be sacrified, simply thrown aside as rubbish. Establish iron works, and you could easily get this ore at so low a cost that it would more than compensate for the additional quantity of coke required to smelt it. It would also remove one fruitful source of complaint from ironmasters at home. If Spaniards had a market nearer home they would be less disposed to send their poor ore to England.

It may be asked, What effect would the success of the Thomas-Gilchrist process have on the ore deposits of Bilbao, or the making of pig-iron in that district? I am not at all apprehensive of any change either for better or worse—certainly not the latter. Supposing it, for argument's sake, possible to make as good steel for all purposes—*not rails only*, but shipbuilding, &c., &c.—from basic pig as from hematite pig iron, Cumberland ironmasters would, I presume, find relief in lowering of the royalties on ore, decreased railway rates, and the development of the local coal-fields. The effect of the latter would be a large decrease in the consumption of Durham coke in Cumberland. This would naturally be followed by a reduction in price of Durham coke, from which the Spanish

ironmaster would receive benefit. Again, the success of the Thomas-Gilchrist process means less consumption of hematite ore. Decrease the consumption of an article, and at the same time increase its productive capacity, and you at once lower the value. Spanish ores would, therefore, be of less value than ever; and here again is a point in favour of making pig-iron on the spot. The success of the Thomas-Gilchrist process, however, has not been assured to us by any results placed before the public. With an increased cost in the plant necessary for the working of the process, an admitted increase in the cost of conversion of basic pig into steel, it appears to me that those who can make hematite pig-iron at the prices I have indicated in a former part of this paper, stand the best chance of holding their own in the present keen competition which is prevalent in every branch of iron and steel manufacture.

This subject might be prolonged to any extent. I would liked to have told you something about the hematite ores of Santander, and then, going still further west, take you into the province of Asturias, a province rich in both coal and iron ore—coal perfectly good enough for smelting purposes, and which, under proper treatment, makes good coke—the ore, a siliceous hematite, containing 45 to 50 per cent. metallic iron, and unfortunately 2·0 per cent. phosphorus, existing in quantities much more abundant than the Biscayan deposits.

I trust in what I have said to-night I may have been the means of communicating information to some whose opportunities have been of a more limited nature than my own, and let me conclude that in what I have spoken I claim no originality. A few plain facts concerning an important industry have been placed before you, in the doing of which I have had the greatest possible pleasure.

NOTE.—For the statistics given in the above Paper I have to acknowledge my indebtedness to the valuable Paper of Mr. William Gill, of the Orconera Iron Ore Company, read before the Iron and Steel Institute, May, 1882.

XIV.—*On the use of Rosolic Acid as an Indicator, with additional Notes on Phenolphthaleïn and Methyl Orange.* By ROBERT T. THOMSON.

[Read before the Chemical Section, 19th March, 1883.]

THE following notes are simply an addition to my former paper on the use of litmus, methyl orange, phenacetolin, and phenolphthaleïn as indicators. The object in view, as I stated before, was to determine the value of each indicator when applied to the estimation of alkalis and free acids, and to ascertain the effect (if any) of the impurities, such as sulphites, sulphides, phosphates, &c., usually found in commercial hydrates and carbonates of the alkalis. The tests were carried out in precisely the same way as described in the former part of this paper.

(1) *Delicacy of Rosolic Acid in absence of interfering agents.*—The solution employed contained 2 grams. of rosolic acid per litre, 50 per cent alcohol being the solvent used. To test the delicacy of this indicator ·5 c.c. of its solution was added to 100 c.c. of distilled water and decinormal hydrate of sodium (1 c.c. = ·0031 gram. Na_2O) dropped in. To effect the complete transformation of the pale yellow to a deep pink colour only ·1 c.c. of the standard alkali was required. This is equal to ·01 c.c. of normal alkali, and this figure should be borne in mind for the sake of comparing the delicacy of the rosolic acid in absence of interfering agents with its delicacy in prescence of the salts to be examined.

(2) *Application of Rosolic Acid to the determination of available alkali in pure hydrate, carbonate, and bicarbonate of sodium and potassium.*—It is hardly necessary to give a detailed account of this portion of the subject. Several tests were made with quantities of the hydrate and carbonate of sodium and potassium containing 1·55 gram. of Na_2O, and 2·355 gram. of K_2O respectively, with the result that exactly these amounts were obtained in each case by titration with normal sulphuric acid. The deep pink colour retains its original intensity up to the point at which bicarbonate of sodium

is produced, but soon gives place to pale yellow, owing to the action of the liberated carbonic acid. It is therefore necessary to boil the solution thoroughly after each addition of acid to bring back the pink colour, and when this is attended to the end-reaction is extremely delicate, and can be effected by at least one drop (about ·05 c.c.) of normal acid.

(3) *Determination of free ammonia.*—Several experiments made in each case with a solution containing ·85 gram. of ammonia (NH_3) gave identical and accurate results. The pink colour remained undiminished in intensity until 49·8 c.c. of the normal acid had been consumed; but on further addition of acid drop by drop, the pink slowly acquired a yellow tinge, and when 50 c.c. had been added the former was wholly eliminated, leaving only the pale yellow colour; but although this is the case, the end-reaction is tolerably distinct. This decrease in delicacy of the rosolic acid is not due to carbonic acid, as the ammonia employed did not contain an appreciable quantity of carbonate; but, as I shall show presently, is owing to the action of the salt of ammonium formed. Rosolic acid has been specially recommended as an indicator for ammonia determinations, but it is evident that it has no peculiar value for that purpose, even the much-abused litmus being considerably superior to it.

(4) *Effect of sulphate, chloride, and nitrate of sodium, potassium, and ammonium.*—The quantities of these salts operated upon were equivalent to 1·55 gram. of soda (Na_2O), 2·355 gram. of potash (K_2O), and ·85 grams. of ammonia (NH_3) respectively. The presence of these salts of sodium and potassium does not sensibly affect the delicacy of the rosolic acid, but each of the salts of ammonium required ·2 c.c. of normal hydrate of sodium to develop fully the deep pink colour, as against ·01 c.c. when tested with distilled water alone.

(5) *Effect of sulphite of sodium.*—The remainder of the experiments were made only on sodium salts, as I did not think it necessary to examine further the potassium and ammonium salts. Two tests were made with 3·15 grams. of normal sulphite of sodium, which contain 1·55 gram. of soda (Na_2O). When titrated in the cold only ·2 c.c. of normal sulphuric acid was required in both cases to destroy the pink colour, but, when boiled, 5 and 5·2 c.c. were respectively necessary, the results being, in the cold ·006, and in the hot ·155 and ·161 gram. of soda (Na_2O). On cooling the boiled solution and titrating back with normal soda, 4·8 c.c. were

required to restore the pink colour. From these results it is evident that normal sulphite of sodium (Na_2SO_3) is practically neutral to rosolic acid in the cold, which it also is, as I showed before, to phenolphthaleïn, while to methyl orange, litmus, and phenacetolin the bisulphite ($NaHSO_3$) is the neutral salt. It is noteworthy that the two last-named indicators give, with the sulphite, very undecided end-reactions, while the three former give very sharp and well-defined end-reactions.

(6) *Effect of thiosulphate of sodium.*—This salt is perfectly neutral to rosolic acid.

(7) *Effect of sulphide of sodium.*—The whole of the sodium in this compound is accurately estimated by standard sulphuric acid, with rosolic acid as indicator. The pink colour retained its original intensity until the sodium hydrogen sulphide (NaHS) was formed, but on further addition of acid gave place to yellow, owing to the action of the liberated sulphuretted hydrogen. On boiling, the pink colour returned, and a very sharp end-reaction was secured. It is only necessary to state that the results agreed substantially with those obtained with methyl orange and litmus.

(8) *Effect of phosphate of sodium.*—Two tests were made with 1·775 grams. of monoacid orthophosphate of sodium, which contains ·775 gram. of soda (Na_2O). In one case 12, and in the other 12·2 c.c. of normal acid were necessary to complete the change from deep pink to yellow. As the transformation in colour was gradual, the end-reaction was extremely unsatisfactory. The results, however, show that the monoacid sodium phosphate is strongly alkaline, and the diacid salt practically neutral to rosolic acid. It is noteworthy that rosolic acid agrees in this respect with litmus, methyl orange, and phenacetolin, but differs from phenolphthaleïn, which indicates the monoacid phosphate as the neutral salt; while normal sodium sulphite is neutral to both rosolic acid and phenolphthaleïn, but strongly alkaline to litmus, methyl orange, and phenacetolin.

(9) *Effect of silicate of sodium.*—With rosolic acid as indicator, the whole of the soda can be estimated by titration with standard sulphuric acid. This must be done in a boiling solution, as otherwise a good end-reaction is not obtainable. The tests were made side by side with experiments made on the same quantity of silicate of sodium and using methyl orange as indicator. The results were identical.

(10) *Effect of alumina.* — The solution employed for each

experiment contained ·775 gram. of available soda, and ·103 gram. of alumina. In one titration 25·2 c.c., and in the other 25·25 c.c. of normal sulphuric acid were consumed, which show ·781 and ·782 gram. of soda respectively, instead of ·775. Rosolic acid thus behaves in much the same way, and gives high results to the same extent, as litmus.

(11) *Effect of nitrite of sodium.*—This salt is quite neutral to rosolic acid.

(12) *Determination of soda in borax.*—Rosolic acid is not well fitted for use in this titration, as the end-reaction is extremely indistinct. A solution containing 1·683 grams. of biborate of sodium ($Na_2B_4O_7$), which is equal to ·516 grams. of soda, was employed; but after the addition of 13·6 c.c. of normal sulphur acid, its pink began to assume a yellow tint, and the former colour was not discharged till 16·6 c.c. had been consumed. This latter result gives ·514 gram. of soda as against ·516 actually present. I showed before that the best indicator for borax was methyl orange, which gives a well-defined end-reaction.

(13) *Determination of free sulphuric, nitric, hydrochloric, and oxalic acids.*—Rosolic acid is an excellent indicator for use in the determination of these free acids, either by standard hydrate of sodium or potassium, the end-reaction being extremely delicate.

(14) *Determination of free tartaric acid.*—For this purpose rosolic acid is not so well fitted as phenolphthaleïn; but the end-reaction is tolerably distinct, and fairly accurate results are obtainable.

(15) *Determination of free acetic and citric acids.*—Rosolic acid is useless as an indicator in the determination of these acids, as, besides the end-reactions being very indefinite, normal acetate of sodium is slightly, and normal citrate of sodium considerably alkaline to this indicator. In this respect rosolic acid resembles litmus, while the delicacy of phenolphthaleïn, and the accuracy of the determinations made with it, are perfect.

It is plainly evident, on taking a survey of the above results, that rosolic acid has no particular superiority over other indicators, unless in some cases the fact of normal sulphite of sodium being neutral to it in cold solutions, may be found useful. In nearly every case it behaves like litmus, and has none of the good qualities not possessed by the latter indicator, but which distinguish phenolphthaleïn, methyl orange, and phenacetolin.

Having now concluded the consideration of rosolic acid, I will

give a few supplementary notes on the use of phenolphthaleïn and methyl orange as indicators.

(1) *Determination of free citric and acetic acids.*—In the former portion of this paper phenolphthaleïn was recommended as being the only perfect indicator for this purpose, but it was not mentioned that the titration should be done in the cold. The reason for this is, that although the normal citrate and acetate of sodium are quite neutral to phenolphthaleïn in the cold, yet when heated they give a slightly alkaline reaction (this is especially the case with the citrate), so that a sensibly high result would be obtained in a hot solution. Of course, in the case of acetic acid a hot solution dare not be used, unless excess of soda is first added, and titrated back with acid.

(2) *Phenolphthaleïn as an indicator in the determination of free ammonia.*—This is a very important point to which special attention should be directed, particularly with the view of correcting some misleading statements that have been published respecting this indicator. I pointed out formerly that phenolphthaleïn was incapable of showing at what point a solution containing a salt of ammonium was neutral, the reason being that such a salt had the effect of destroying the red colour produced by the ammonia, even when the latter was present in considerable proportion. Phenolphthaleïn has, however, been directly recommended as an indicator for ammonia by one author, and the monoacid phosphates of sodium, potassium, and ammonium have been stated by another chemist to be neutral to it. This is true as regards the phosphates of sodium and potassium, but with the ammonium salt no definite neutral point is obtainable owing to the decolourizing action of the salt itself. The experiments made by these chemists have evidently been confined to potassium and sodium salts, while the behaviour of the ammonium salts have been simply assumed from these results. These facts show how incorrect statements may be made by trusting solely to the analogy between the salts of the alkali metals and ammonium.

(3) *Valuation of phosphate of sodium or potassium and phosphoric acid.*—In the former portion of this paper I had occasion to describe the behaviour of normal orthophosphate of sodium and potassium when titrated with sulphuric acid, methyl orange and phenolphthaleïn being used respectively as indicators. The neutral point with methyl orange is reached when the diacid phosphate (NaH_2PO_4 or KH_2PO_4) is formed, while with phenolphthaleïn

the neutral salt is the monoacid phosphate (Na_2HPO_4 or K_2HPO_4). On this definite difference of indication (which represents exactly one-third of the phosphoric acid present) I have ventured to base a process, which gives fairly accurate results, for the valuation of any of the orthophosphates of sodium or potassium, or of phosphoric acid. This is certainly a determination that is seldom required, but a rapid process of this description is at least of some interest, and may occasionally be found useful. The method consists in adding to 5 or 10 grams. of the sample, previously dissolved in about 80 c.c. of water, normal sulphuric acid from a burette till the faintly-acid reaction with methyl orange is obtained, or, in the case of phosphoric acid, normal caustic soda is added to the same point. The amount of acid or alkali added need not be measured, as the object is simply to add exactly enough to produce the diacid phosphate. The mixture is now boiled for a short time to expel carbonic acid, if present; then cooled (if the solution is kept hot a low result will be the consequence), a little phenolphthaleïn added, and the titration accomplished by normal caustic soda or potash, one c.c. of which will represent ·098 gram. of phosphoric acid (H_3PO_4), or ·142 gram. of monoacid sodium phosphate (Na_2HPO_4). Several tests were made of a sample of ordinary phosphate of soda, the results being controlled by two determinations by precipitation with magnesia mixture. The following were the results—

By Alkalimetric Method.			By Precipitation as $Mg_2P_2O_7$.
Grams. of Phosphate of Soda tested.	c.c. of normal NaHO consumed.	Percentage of Na_2HPO_4.	Percentage of Na_2HPO_4.
10	28·1	39·90	40·29
5	14·1	40·04	40·35
5	14·1	40·04	...

The theoretical percentage of dry phosphate of sodium in the crystallized compound is 39·66. It will be readily seen, from the nature of the process, that the presence of carbonate, sulphate, chloride, nitrate, thiosulphate, or sulphide of sodium or potassium, will not influence the accuracy of the results. If sulphite of sodium is present, it must first be oxidized to sulphate by the addition of a little peroxide of hydrogen (excess of which does

not affect the delicacy of the indicators), as otherwise a high result would be obtained.

It will be observed that I have not noticed the application of phenolphthaleïn as an indicator in the determination of caustic alkali in soaps, of free and combined fatty acids in oils and fats, and of resin acids—the reason being that this subject has been fully entered into by various chemists.

In conclusion, I may state that I am examining further the behaviour of phenolphthaleïn, methyl orange, phenacetolin, rosolic acid, litmus, and other indicators, with other chemical compounds, having in view the special object of extending their employment, if possible, in the analysis of commercial chemical products.

XV.—*Closing Address to the Architectural Section.* By JAMES SELLARS, JUN., I.A., President of the Section.

[Read before the Section, 26th March, 1883.]

THE work of the present session ends to-night, and it is my privilege to have the last word. Presidential utterances are supposed to be indisputable, and therefore it is, I presume, that no discussion is expected. I do not know if this is an advantage, however, as it restricts very much the kind of subject which one might choose, and debatable matter has to be avoided as far as possible. My remarks will be very general. I shall confine myself to a few references to the work of the past session, and afterwards make some observations on matters of public interest —matters, however, in which the members of this Section have a *special* interest.

The life of any body or society is very like the life of an individual. To preserve a healthy, vigorous condition, it must not only have some useful work to do, but it must endeavour to do it well; and if it does so, even although the results are not everything which could be desired, it will be able to look back on each year of its life with the feeling that it has not existed in vain.

Now, I venture to think that we, as a society, may lay claim to having done good useful work during the past year—work which, I think, has not only been useful and instructive to ourselves, but of some public service. In a greater degree than is the case with most societies of a similar kind, the subjects we discuss have an interest outside the narrow limits of our membership. The arrangement and construction of buildings is our daily work, and subjects connected with that are of special interest to us; but the general public are also deeply interested in such matters, and are becoming more so every day. I think it is fortunate that this is so. The more they know of the subject, and the more they are able to appreciate good work when they get it, the better it will be for

those who endeavour to design and construct buildings which will fulfil the requirements of good taste, sound construction, and sanitary science.

Nearly all the papers read during the past session have been of an eminently practical kind. On the opening night we had a paper from Mr. John Dansken, on "Building Construction, with Special Relation to Protection from Fire"—a subject evidently requiring attention, in view of the unprecedented number of fires which have taken place during the past year, many of which, I have no hesitation in saying, are due to malconstruction or careless and reckless execution of work. Very much more stringent regulations must be made in regard to buildings being constructed so as to minimise the chances of fire, and to localize it when it does occur, either in the new Police Bill or in a separate building Act. I shall pass from this, however, in the meantime, as I mean to refer to it further on.

Then followed a paper by Mr. John Hay, on "Ventilation considered in relation to the opposite Seasons of the Year"—also a subject of great interest, both to those who have to do with the arrangement of buildings and those who have to use them. When it is considered how much the comfort of large numbers of persons is affected by the arrangements made for the ventilation of the apartment in which they are assembled, the importance of the subject cannot be overrated, nor can its difficulties be exaggerated. Mr. Hay considered the question in relation to the opposite seasons of the year—that is, the different provisions requiring to be made for ventilation in summer and in winter; and, no doubt, it is possible to arrange an adequate system of ventilation for these two seasons, provided that we have a temperature such as we are entitled to expect from the relative position of the earth and the sun in summer and in winter. But the fact is that in this climate no two days are the same. In winter we may have an intensely cold day, followed by a close muggy one—in summer a warm, genial day, and next day a piercing cold east wind. Under these conditions a ventilating apparatus, however perfect, requires intelligent manipulation. I fear it is a very general experience, however, that the ventilating and heating apparatus—which must always be considered together—of churches and halls are worked without any special regard to the outside temperature on a particular day. It is enough that it is the winter months, and it *ought* to be cold—the fires go on, and any openings which would admit fresh air or

carry off foul air are shut; although the temperature may be such as to require no artificial heating whatever; or it is the summer months, and it *should* be warm—therefore there is no heating, all the air openings are open, irrespective of the cold wind which may be blowing, when the closing of such openings and a modified heat would be an advantage. If I might make a suggestion to Mr. Hay, it would be that he should prepare a paper on the management of heating and ventilating apparatus, which might be published with great advantage. He would confer a boon on the public and the profession. The most careful planning of interior arrangement, the most comfortable seating, the most charming and refined detail, the most gorgeous and impressive decoration is utterly lost, and the architect gets no credit for such things if the public have to listen to the sermon or the symphony with their coat collars turned up and a desire to put on their hats, or feeling that existence would only be endurable if they divested themselves of more clothing than public decency would permit.

Then there is the other difficulty, which, I fear, the most scientific heating and ventilating apparatus and the most careful management of the same, will not overcome—viz., that there may be in the same building persons whose bodily condition requires the temperature of an oven, and others unhappy if the temperature is much above freezing point; persons who consider the admission of fresh air in any form a disagreeable draught, and others who welcome it as a balmy and refreshing breeze.

Following this paper we had excellent practical papers from Mr. James Goldie and from Mr. C. P. Hogg, C.E., on "Bricks and Brick-making" and "Foundations"—the former a subject regarding which we in Scotland require enlightenment. Brick as a building material is not, in my opinion, utilized as it might be here. There is what I venture to call a stupid prejudice against its use. The capabilities of the material are not well understood; we have only to look at what is done in England and elsewhere to realise this.

The brick-makers and builders are to blame to a large extent. They don't respect the material themselves. In England each brick intended for external use is tenderly handled and cared for from its earliest state till it is placed in the wall. Here the bricks are treated as if they were so many pieces of coal; and indeed, by the time they reach the building and are discharged *en masse* out

of the cart, they have hardly any more pretension to shape than pieces of that useful mineral.

For internal purposes, however, they are coming into more general use. For backing up the stone facing of a wall, I think they are to be preferred to ordinary rubble building. Of course, used in that way, they increase cost very much; but the money is well spent. Several buildings in Glasgow have been erected in that way, and I understand that the new municipal buildings are to be so built. It should be mentioned here, however, that a wall built in that way is open to the objection that it will not stand the action of fire to the same extent. Captain Shaw, the chief of the fire brigade in London, speaking of composite walls and the action of fire on them, gives it as his experience that they will fail where a wall entirely of stone or of brick will stand. This a fact worth noting.

Mr. Hogg's paper on "Foundations" was also an important one, and very instructive.

Then we had a most interesting and valuable paper from Dr. Wallace, the President of the Philosophical Society, on "Building Stones"—a subject deserving great attention in Glasgow in view of the important buildings in immediate prospect. Far too little attention seems to have been given to the proper selection of building stone hitherto. Buildings in Glasgow erected 40 or 50 years ago seem to weather better than buildings erected during the last ten years. Whether this is in consequence of our local stone having deteriorated in quality, or that the older buildings had got seasoned before the atmosphere of the city was so smoke-laden and impregnated with injurious gases from the numerous chemical works, I am unable to say. But Glasgow air is not likely to improve, and it is, therefore, all the more necessary to select the stone best fitted to resist its chemical action.

I think, however, that the somewhat remarkable extent to which buildings in Glasgow, erected during the last eight or ten years, show evidence of decay, may be partly accounted for by the extraordinary demand for building stone during that time, resulting in material being used which, in quieter times, would have been rejected as unfit for use, or stones being used immediately on their being cut from the quarry, without a chance of being seasoned. An eminent authority says—"Nearly all stone is the better of being seasoned by exposure to the air before use, to get rid of the moisture called quarry sap. Unless this moisture is

allowed to dry out before the stone is used, it is acted upon by frost, and thus the stone is cracked or disintegrated."

It seems reasonable that stone should be seasoned just as timber is seasoned. Fortunately we cannot cut down a tree, which in the morning has been adorning the landscape, saw it into joists and flooring to be laid in the building before night, or, I suppose, in these busy times I have been alluding to, we would have done so. Yet that is how we deal with stone, which, in the morning, we may cut from its bed where it has lain for thousands of years, and lay it in another bed—and that not always its *natural bed*—before night. I fear these so-called good times have not been an unmixed blessing. In connection with his paper, Dr. Wallace procured a number of specimens of stones from the neighbourhood and elsewhere—all of them, however, from quarries sufficiently near Glasgow to make their use practicable here—and these he had tested chemically to ascertain their weather-resisting and other qualities. He also prepared a table showing the result of his analysis, which table, along with the paper, will be published in the *Transactions* of the Society, so that this section has been the channel through which information of a most useful and valuable kind has been made permanently available.

Then we had a paper from Mr. John Honeyman on a subject which is at present engaging considerable public attention—viz., the proposed removal of St. George's Church and steeple. Speaking from an architectural point of view, I suppose no one cares how soon the church is removed if the steeple is retained. As far as one can judge from the discussion at the last meeting of the Town Council, there appears to be a strong probability that it will not be removed. A considerable minority of the Council would stop the negotiations for the disposal of the site if they had their way, and of those who agree to their proceeding meantime I presume there will be many who would resist any bargain being entered into which would involve the removal of the steeple. On the whole, I think the chances are strongly in favour of this fine work of one of Glasgow's most distinguished architects continuing to raise its dignified and graceful proportions heavenward, unhurt by the aspirations of advertising insurance offices, or the well-meaning but quite too utilitarian ideas of municipal economists.

Following Mr. Honeyman's paper, and on the same evening, we had a good useful paper by Mr. T. L. Watson on "Square Dressed Rubble."

At last meeting, Mr. William Landless read a paper entitled "The Rival Cities"—the cities referred to being Edinburgh and Glasgow. Mr. Landless' paper contained a great deal of useful and interesting information imparted in a pleasant way. Statistics were given showing the comparative areas, population per acre, death-rate, water supply, &c., &c., and some comparison was made as to the natural advantages of the two cities, their architecture, &c. Alluding to this paper, at a meeting held the other night, Lord Provost Ure said that he did not know of any rivalry which ought to exist between the cities except the rivalry in good works. I think every one will agree with his Lordship in this. He was speaking at a meeting held under the auspices of the Glasgow Sanitary Protection Association, and no doubt the good works he specially meant at the time were works undertaken on behalf of the public health. In such matters there ought to be a desire for pre-eminence in every well-governed city—a rivalry in matters of that kind would serve a useful purpose; but I see no good in pitting the two cities against each other in respect of their situation, their public buildings, their art culture, or their importance politically and socially.

Edinburgh is the favoured child of nature. It might be said to have been born with a silver spoon in its mouth. Nature has made it the most beautiful and picturesque city in the country. It is the capital of this end of the kingdom, enjoying all the advantages which accompany that position—the seat of the legal and the church courts, the home of the Royal Academy of the Fine Arts. It has a famous university—its sons are foremost in literature and in art. Its ancient streets and buildings are associated with the most important historical events—its modern streets and buildings are stately and even magnificent. All this can be said of Edinburgh. Of Glasgow it may be said that it is like the self-made man. With a very humble origin, it has made itself what it is by its own efforts, the chief commercial city in Scotland, and in the very front rank among cities in the kingdom for its industries and manufactures. Less than a century ago a comparatively unimportant town, situated on the banks of a quiet fishing stream; now, a great city teeming with busy workers jostling each other in the battle of life; with a great river running through it, on whose banks are built the finest vessels and whose waters carry shipping laden with merchandise destined for all parts of the world. Its ancient cathedral, streets, and buildings are not wanting in historic

interest. It, too, has stately streets and magnificent modern buildings. Its university is world-famed, in science its sons take the foremost rank; its art culture is not less than other cities the great mass of whose inhabitants are engaged in trade and manufacture. But all these things can be said as a simple statement of facts, and not in a spirit of rivalry.

To-night we have had two very useful papers on practical subjects from Mr. John Cowan and from Mr. W. Howatt—the first on "Knots in Timber," the other on "Instalments." Short suggestive papers of that kind ought to be encouraged in this Section. They give an opportunity for a larger number of our members taking an active part in the work of the section, and their preparation does not involve any great trouble. Most people have some speciality regarding which they would be able to make a communication of practical value. I think the Council will do well to keep this in view in arranging the work for the next session. Probably every second night should be devoted to the reading of two or three such papers.

I think I have said enough to justify my opinion that this Section has done good useful work during the session now drawing to a close; that it is in a strong, vigorous, healthy condition, and ready for more work. I now proceed to refer to the subjects which I alluded to in the outset of my remarks as being of general public interest and special interest to us.

The first question to which I ask your attention is by no means a new one; but a fresh impetus has been given to it in connection with the new Police Bill which has been framed by our authorities during the past year. You are, no doubt, aware that the present Police Bill contains all the regulations affecting buildings in force in Glasgow. In view of a new bill being promoted, it is thought by the architectural profession generally, and others more or less interested in the subject, that the opportunity has come—the time having come long ago—for separating the building regulations from the Police Bill, and making them the subject of a separate act. This view is held very strongly indeed by the Glasgow Institute of Architects, a body of professional men whose opinion on a subject of that kind is surely entitled to some degree of respect. In 1878, when the authorities endeavoured to obtain a provisional order—which was to sanction more stringent regulations in regard to buildings than those contained in the Police Act of 1866—the Institute, in common with other public

bodies, opposed the order, not because they did not think more comprehensive building regulations were required, but for the following among other reasons set forth in their "objections," viz. :—"We object to *any* alteration of the clauses of the Police Act relating to buildings, because we are unanimously of opinion that the many important interests involved can only be satisfactorily dealt with in a comprehensive building act."

Again, while the Town Council was discussing the clauses of the new bill—which proposes to continue the principle of including building regulations in the bill—the Institute took action in the matter, and unanimously resolved as follows :—

"1st. That it is expedient that the clauses relating to buildings and the jurisdiction of the Dean of Guild Court be omitted from the Police Bill.

"2nd. That the laws relating to buildings should be consolidated and amended by a new act dealing with that special subject, similar generally to the Metropolitan Building Act, and applicable to the suburbs as well as the city of Glasgow."

These resolutions were forwarded to the Town Council, but they have not seen their way to make any change of the kind desired. The building clauses have been retained in the draught bill which has been forwarded to the Lord Advocate as the kind of bill, I presume, which would, in their opinion, be the best for Glasgow. But for the Lord Advocate announcing his intention to bring in a general police bill for Scotland, no doubt the bill, as framed, would now be before Parliament. I cannot help thinking that it is fortunate for all parties that it has been delayed—where there was so much smoke there must have been some fire. No doubt something could have been said by the opposition—of which the Institute formed only a small part—and as they did not get a hearing in Glasgow, they would have taken steps to make themselves heard in the committee rooms of the Houses of Parliament, where the maxim that "silence is golden" is reversed. Speech is golden there, as both the promoters and the objectors would have found, and the gold would have had to be provided by the public. More time for consideration may lead to concessions on both sides—the fire of opposition may be quenched, or it may end in smoke only; or possibly the Lord Advocate—to whom representations will, no doubt, be made—may see good grounds for giving effect to

the views of the opposition, at least so far as not to include building clauses in his bill.

In view of this possibility, I wish briefly to indicate what is provided in the Metropolitan Act—the act which has been pointed at as the model which we might adopt—to ensure the structural safety of buildings and protection from fire. These are the two things dealt with most summarily in the Police Bill, while they are just the things which the London act deals with in great detail. I will not take up time at present by referring to the provisions in the act for securing the rights of adjoining owners, public health, or the regulation of the street frontages, &c., &c., except to say that, as regards provisions for public health, it is very defective. These are provided for in other acts to some extent, but, in regard to sanitary provisions, our own Police Bill does better for us than all the London acts put together. Of course what is good in that respect ought to be secured in the proposed new act.

Before describing what is provided in the London act for the purposes referred to, let us see what the Police Bill does in the same direction.

As regards construction, all that is contained in the Police Bill is the following (clause 371):—

"The Dean of Guild shall not grant a warrant to erect or alter any building unless or until he is satisfied that the plans and sections make satisfactory provision with respect to the several matters specified in this section, viz.—(1) That the outer walls, and the party walls, or separate side and end walls, and the joisting and principal timber and iron work, as shown on the plan, are of sufficient strength and stability."

That is considered by the advocates for a separate act as far too general, and that it would be much better if such matters were clearly defined as anything about a building which is necessary for public safety can and ought to be clearly defined. Further, that these things should not be left to the opinion of the officials for the time being—whose duties, they say, should not be to advise or prescribe what they may consider best, but rather to ascertain and declare if what is defined in the act as necessary for the public safety has been done. That is what the Metropolitan Board of Works does through its district surveyors. Let me now indicate what is defined in the Metropolitan Act in regard to structural safety. I have collected my facts from a text-book of the act by

Mr. Banister Fletcher, and I am also indebted for much information to a paper read to the London Architectural Association in 1876 by Mr. T. Roger Smith. Both these gentlemen are district surveyors, and first-rate authorities on the subject. By far the most important of the regulations are those which deal with the construction of walls, their thicknesses in proportion to their height and length, their foundations, footings, and materials. The kind of materials to be used, and the manner in which they are put together, are specified. The footings, or foundations, as we say here, must be of a width proportionate to the wall they support. I observe that the rule is that, if the wall is 18 inches thick, the foundation requires to be 30 inches wide; if 24 inches thick, then the foundations have to be 48 inches wide, and so on in the same proportion.

The thicknesses of walls in proportion to their height and length are determined by certain tables. The strengths necessary for buildings of the warehouse class and the dwelling-house are also specified. There are also regulations as to recesses which may be made in outside walls and party-walls, so as not to injure their stability.

Bond timbers are not to be built into any party-wall, and no timber of any kind can be built into a party-wall nearer than 4½ inches off its centre line, &c., &c. In Mr. Roger Smith's paper, to which I have referred, he says—"The act secures that buildings, or more properly the walls of buildings, shall be fitted for their special purposes; but it does not attempt to secure that degree of general solidity and excellence which any person may secure for himself by the employment of a competent architect, and it gives only an indirect control over the construction of roofs, floors, or partitions, so far as relates to their structural stability."

Then as to the regulations in regard to protection from fire. Let us, as before, see what the Glasgow Police Act does in that direction. Quoting from the same clause as before—where it is provided that the Dean of Guild will not permit any building to be erected until he is satisfied on certain points detailed in the following sub-sections:—

"(4) That the joists under every hearth shall be bridled.

"(5) That every fireplace shall have jambs projecting at least to the flush of the plaster.

"(6) That no joists shall be inserted into a wall nearer to a chimney than 12 inches."

Now, as far as they go, there is no dubiety here. These are clear enough rules. Nothing is left to individual opinion, as is the case in sub-section (1) dealing with strengths of walls, &c., and which only provides that they are to be "sufficient" in strength and stability, without saying what is sufficient The only question regarding the fire protection clauses is, do they go far enough? They are altogether new clauses—there are no such clauses in the present act at all. I may remark here that Liverpool has had a separate act expressly for the "Better Protection of Property from Fire" for the last 40 years.

Let us see what the Metropolitan Act provides.

First, as to provisions for preventing a fire from taking place. There must be a hearth at every fire opening, and every hearth must be carried on brick trimmer arches, unless it is on the ground floor, where it must be built up solid from the ground. The back of the fire must be at least 9 inches thick, and the openings must have an iron chimney bar. The floor under and for 18 inches round every manufacturing oven or stove is to be of some incombustible material. The rules as to keeping timber away from flues are very stringent, and most minute in detail: no timber of any kind is to be nearer than 12 inches to a flue, nor under a hearth nearer than 18 inches.

Second, as to the preventing of fire from spreading. The rules as to thickness of party-walls come into use here. Then party-walls must be carried up through the roofs at least 15 inches above the adjoining roof, and if there are projections above the roof, such as a dormer window or a lantern light, then the wall must be carried up 15 inches above the highest part of it.

Third, so as to control the bulk or extent of a fire. In the case of warehouses and similar buildings, a limit is placed on the size which any one building may be. It must not contain more than 216,000 cubic feet, and if any two buildings adjoining, in the same occupation, would together amount to that size, then the openings between them are not to exceed certain limited dimensions, and to be protected by two iron doors.

Staircases and corridors in public buildings are to be constructed of stone or other fire-proof material. I will not go further into the details of this act, as I have already exceeded the limit of time at my disposal, and I have other matters to refer to. I have simply wished to indicate the manner in which building regulations, dealt with in the Police Bill in a few clauses, are treated

in the Metropolitan Building Act, and it is probably fair to assume that if these things require to be dealt with in such detail, then a separate act will be necessary. The subject would become far too large to be treated as part of a Police Bill.

There are two new clauses in the Bill, which have been adapted from the model bye-laws of the Local Government Board, and which are admirable in their aim and intention. The first provides for the proper construction and ventilation of drains, the other for a sufficient excavation being made under tenements, and, where the soil is artificial—that is, on a site which has been filled up with *debris*—it is to be covered with a layer of concrete. That is a most important provision. It does not exist in the Metropolitan Act, but it is provided for under certain bye-laws made by the board under the provisions of the Metropolitan Management and Building Act Amendment Act, 1878. Before leaving this subject, permit me to say a word as to how the act is carried out. The work of the Metropolitan Board of Works and their district surveyors is purely administrative. They do not make the laws, they have simply to see that the provisions of the act are adhered to in the plans, and carried out in the erection of the building; and if the builder fails to do so, he is summoned to appear before the nearest magistrate, and dealt with there.

The members of the board are elected by the various vestries in London, of which they must be members, and they have a consulting architect. The board elect the district surveyors from a body of gentlemen who have passed an examination by the Royal Institute of British Architects, and they are not eligible for election unless they have done so. The district surveyor is paid by fees received from the persons erecting the buildings.

There are many other matters relating to buildings in the new Police Bill—such as the free space to be provided between them, their height, the height of the apartments within them, and the allowance of air space per person in each apartment; the new regulations to abolish hollow squares, which I shall merely name, and say of them generally that the changes proposed are, in my opinion, in the right direction. And I say this, although I am aware that many of my professional brethren are of opinion, not only that a 9-feet 6-inch ceiling in a dwelling-house is not essential, but that it is not so good as a lower one, the air space in the room being the same; and that some of my hearers, more directly interested in property (as owners) than I am, will say

that the abolition of hollow squares, and the greatly increased spaces between buildings now proposed, would amount to confiscation of property.

There is just one other point advanced in favour of a separate building act which I will refer to before changing the subject—viz., that it could be made to embrace not only Glasgow, but the suburbs—and that is certainly most important. No matter how perfect the arrangements inside the municipal boundary might be, the good effects would be very seriously impaired if it were surrounded with a cordon of suburbs containing houses badly constructed and insanitary.

We have done very well in the past with building regulations in the Police Act—the city has improved and extended under them; but that is no reason why we may not do better. If there is to be a change, there can be no doubt but the present is a fitting opportunity. The present Police Act has been in existence since 1866, and we may assume that, if the new one becomes law, its life will not be shorter; so that, say its opponents, we would practically be tied up to a system which the city has already outgrown, during a period in which it will still further extend, and long before the expiry of which even the improved machinery of the new bill would be found quite inadequate for the purpose.

I trust I have been able to put some facts before you in regard to this important subject, the consideration of which may possibly enable those whom they reach to form an opinion when the proper time for discussion comes. I do not think that the question is at all settled, otherwise I would be taking up your time to no purpose.

Another matter which concerns us very nearly is the greatly increased interest which is now being taken in sanitation by the authorities and the general public. To no one individual is Glasgow so much indebted for this condition of things as to Lord Provost Ure. All through his long municipal career his name has been associated with good work in the direction of improving the sanitary condition of the city. As we have seen, the new Police Bill contains clauses regulating buildings, in relation to their position, construction, and occupancy, which would do a great deal in that direction, and they ought to become law.

Recently the sanitary department have begun a new branch of work, viz.—drain-testing—and the results, as shown by the first annual report by the sanitary inspector, are somewhat alarming.

Out of nearly 300 drainage systems inspected, only six were found to be in a satisfactory condition. Similar work done by the Sanitary Protection Society has had similar results. Now, if these reports are a fair representation of the facts, they show a very unsatisfactory state of matters. If they are true, drain-testing, whether by the public authorities or by private associations, has not been begun a day too soon; and I think the public—and especially the section of them whose business it is to design and construct the drainage system of houses as well as the houses themselves—are very much indebted to these two organizations for bringing the subject into so much prominence. The importance of house sanitation cannot be over-estimated, and it must be admitted that it has not generally received so much attention as it deserves. There seems no need, however, for gentlemen calling themselves sanitary specialists, in their new-born zeal, assuming that they are the only persons having any knowledge of the subject. In Glasgow we have medical men, aye, and architects too, who have for years made sanitation a subject of special study. It is too much the fashion to abuse the architect. He is the favourite butt of the riders of all sorts of hobbies, who charge him full tilt, and endeavour to find a crevice in his armour that they may overcome him, and glorify themselves over his prostrate form. He seems a convenient peg on which to hang all sorts of complaints; a sort of buffer placed between the public and the alleged sins of the builder and the plumber; a shield to receive the blows of righteous indignation, which ought to fall on the layers of unjointed drains, the makers of unventilated traps, the constructors of insanitary houses.

It would be quite right that this shquld be so if architects were always employed to design and superintend the construction of houses. Professor Fleeming Jenkin, in his lecture on "House Sanitation" the other evening, said, in explaining the need for sanitary protection associations, that all architects were not specialists in sanitation, and that many houses were erected without having any architect at all. Both statements were true, and the latter to a much greater extent than is generally known. Not to speak of whole districts in the city erected by builders innocent of an idea on sanitation, go outside the boundary into the fashionable suburbs and what do we find? Acres covered with terraces, and villas, and mansion-houses, the majority of which are not the work of an architect, or if the name of an

architect is associated with them, in a great many cases he is responsible only for a sort of show plan and elevation which he has prepared for the builder, to satisfy the superior of the ground as to the *size* and *external appearance* of the houses, and the buildings are afterwards erected without any professional supervision at all.

So much for the majority of new houses and the share of blame which may be justly laid at the architect's door for their insanitary condition. Then, as to the older buildings, which may or may not have been designed by and constructed under the supervision of an architect, it must not be forgotten that when they were erected they would in all probability have been pronounced satisfactory by the most learned sanitarian of the period, although their arrangements are condemned *now* in the light of advanced sanitary science. It would be just as reasonable to find fault with the construction of a house which was not provided with telephones or the electric light, although it had been erected years before these things were invented, as to condemn the architect or builder of a house because it did not contain appliances unthought of even by the sanitary specialist of its time. I have been chiefly led to make these remarks because, in the course of the lecture I have been referring to, the speaker, while endeavouring to make his remarks on a rather prosaic subject both instructive and interesting, managed to make it at least amusing by sundry references more or less direct to the stupidity or worse, of architects, builders, and plumbers. It was all very good-natured, no doubt, and was probably meant to impart a little sparkle to a dull theme—to give a little pleasant flavouring to a somewhat unsavoury subject. It served, however, to show the popular tendency, the readiness to make and to believe in any kind of charge which may be made against all branches of the building trade. Except for that there would be no excuse for my treating it seriously at all; but I wish to point the lesson to be drawn—increased study of such subjects on our part, a greater exercise of care in seeing our designs carried out by the workmen. We are greatly indebted to the learned professor for coming here and instructing us in this important branch of science, and we welcome him as a fellow-worker in the same cause — the improvement of house sanitation.

Along with greater attention to such matters on the part of professional men, a specially-trained class of workmen is required

—the laying of drains has been too much left to the mason's labourer.

The public attention now drawn to the subject will no doubt lead to much-needed reform. House sanitation is a most fitting subject for discussion in this section, and I trust it will receive the consideration it deserves.

Another question which I think may well claim our attention is one which I have before referred to in this section—viz., the providing of proper dwellings for the working-classes. I do not mean what I may call the well-to-do working-classes, the earners of 25s. to 35s. per week. We will say that they are well enough provided for in the ordinary tenement so common in Glasgow, although I am of opinion that something might be done for that class of dwelling too. I mean a class of the population which belong to a lower strata, if I may so put it; people belonging to the labouring classes, earning less than 20s. a-week, and who are, with every desire to live in a respectable way in their own sphere, obliged, from circumstances which they cannot control, to herd together—you cannot call it anything else—with the very dregs of society, the criminal classes. I suppose there will always be in every large city a certain proportion of the population who will be content to inhabit the filthiest dens, dark and noisome hovels; who will indeed prefer to do so because their avocations will not bear the light of day. But can nothing be done to separate the respectable labouring classes from this class? Can we not provide them with dwellings in which they might be cleanly if they chose to be so; in which they might have a chance to breathe a purer atmosphere, moral and physical? I think we could, and it ought to be tried.

The chief difficulty is the price of ground in the city; the impossibility, indeed, of obtaining ground near the centre of the city on which such buildings could be profitably erected. I see no great difficulty about the building, if ground could be obtained at a reasonable rate. That is where the shoe pinches; because a large number of such persons must be accommodated inside the city. If we could take them outside the city—and with the tramway system extended and the prospect of suburban railways which we now have, that seems feasible enough too—the difficulty would be greatly lessened. Such buildings would have to be of brick; and here my friends who say that heights of ceilings and distances between buildings must not be defined by a hard and fast line,

either in the city or elsewhere, will remind me that, if these houses are erected to pay it will never be with 9-feet 6-inch ceilings, or with spaces between them equal to one and a third times the height of the building. Well, I am afraid they will have the best of the argument there; and that is just a question for the consideration of framers of such regulations, whether they are in a police bill or a building act. The problem is undoubtedly a difficult one, and whoever can solve it will deserve well of the city. I recommend it for your consideration.

I have occupied a much longer time than I proposed to do when I began my remarks. I hope the various matters which I have alluded to will suggest many subjects to be taken up by members of our section, and may form, in short, a kind of groundwork for our next year's syllabus.

In bringing my remarks to a close, I trust the section will go on increasing in usefulness, and that next session we will begin work after the summer recess with fresh interest and renewed vitality.

XVI.—*The Water Highways of the Interior of Africa, with Notes on Slave Hunting and the means of its Suppression.* By JAMES STEVENSON, Esq., F.R.G.S.

[Read before the Society, 28th March, 1883.]

BY the title of this paper I wish to indicate that my object is not entirely scientific. My purpose is to show what use can be made of the water systems of Central Africa; and so far my remarks will be of the nature of what the Germans call Commercial Geography.

The map I exhibit of East Africa is the part completed of the great map of Equatorial Africa, now in preparation by Mr. E. G. Ravenstein for the Royal Geographical Society. The scale of this is about 16 miles to an inch. The diagram, or map, which I also exhibit, has been prepared for me by Mr. Ravenstein, in order to make known to you all the most recent discoveries throughout Equatorial Africa. The scale is 1 to 1,775,000, or 28 miles to an inch. The river courses are boldly drawn for the purpose of being seen at a distance. In some cases, where these courses between certain points are inferred, or are derived from native information, they are sketched in continuous lines on this map, in place of being dotted as in the other, for which Mr. Ravenstein is responsible; but I believe this is done in no case where the probability does not approach to certainty. For publication, a copy of the diagram, or map, has also been prepared on the scale of 1 to 23,000,000—*i.e.*, 370 statute miles to the inch. It may be as well to state that I shall always reduce distances to statute miles.

The part of the continent of Africa which is marked off with continuous lines in the index map exceeds six million square miles in extent—equal to twice the area of Europe, or to the whole habitable regions of North America, or to four times the area of India, British and Independent. Extending to 20° north lat. and 21° south lat., the region is entirely tropical. The desert encroaches to some limited extent on the northern extremity, and

some of the higher lands on the east side are intractable; but the country is to a great extent capable of high cultivation.

Hydrographically, the rainfall follows the course of the sun; in the northern hemisphere the rainy season commencing in May, and ending in November; in the southern, beginning in November and ending in May; in the equatorial belt, which extends to several degrees on either side of the equator, the rainfall being in both seasons of the year. Near the east coast the monsoon modifies these conditions, but does not affect the interior. Observations as to the amount of rainfall are still in their infancy; but at Lake Victoria about 50′ inches are indicated, which was probably diminished by the attraction of mountainous regions to the westward. At Bandawe, 12° south on Lake Nyassa, the fall was 80 inches; but at Cape Maclear only 30 inches, and at Teté 35 inches—showing the influence of local conditions.

With the exception of the country north of the equator and east of 34° long., where Semitic and Hamitic races have come in, the whole population is of purely African origin. In the regions in question, the races south of the equator belong to the great Bantu family, who are believed to have fought their way from the N.E. On the West Coast they are found even so far north as 5° north lat. The purest type of this family of nations is found, perhaps, in the Amazulu and Amaxosa, Kaffir tribes of South Africa; elsewhere they are more or less intermixed with the races they superseded. The language is agglutinative, and the different tenses of the verbs, etc., are formed by prefixes, in a way somewhat analogous to the Semitic tongues. Hence it has been called Sub-Semitic; but it is distinguished from any other language by essential peculiarities. The language is of a high type, and the verb exceptionally rich in forms. The best authorities reckon that the Bantu countries extend 3,388,000 square miles, and that the inhabitants averaged seventeen per square mile. This estimate would give a Bantu population of fifty-six millions, of which three-and-a-half millions are in South Africa, where the tribes are mostly pastoral. Perhaps some deduction must be made from this total now that dense forests are found to cover a very large area on the Congo; but, in any case, the Bantu remain one of the great races of the human family. West of 34°, and north of the Bantu tribes, come in everywhere the Negro or Nigritian races, which are entirely distinct from the Bantu. These extend beyond our limits to the extreme west—their proper domain including nearly the

whole of the Sudan, from Cape Verd to Khartum. Their languages vary much, and there has been found as yet no ruling type. Bordering on the deserts of the north is what is called the Nuba-Fulah race, to which belong, on the east side, the people of Dongola, and, on the west side, the dreaded Toucouleurs of Senegambia. These tribes have become generally Mahomedan, and have preyed on the Nigritian races on the south of them, who seem deficient in that cohesion which is requisite for tribal or national defence.

The only further remarks of a general character which I shall make refer to that subject of painful interest—the slave trade. Domestic slavery, generally of a mild type, may be said to prevail throughout the entire continent. Many of the chiefs were also in the habit of thus getting rid to slave dealers of *mauvais sujets* among their people as well as of captives taken in war, and were perhaps disposed to draw a wide line in regard to this exercise of their sovereign rights. While the best weapons of the slave hunter resembled the old brown bess, the tribes were tolerably able to defend themselves from serious attack, and the slave dealer did not venture very far inland. The suppression of the export of slaves from the West Coast also put a stop to the devastation of that part of the country. But of late years, owing, I believe, chiefly to the immense superiority of the weapons of the attacking party, there is little check, and great part of the interior is a prey to ruffians of the worst type. On the slave route map exhibited, some attempt is made to indicate the parts where the tribal organisation is more or less broken up and the population in some measure destroyed. In preparing this I have had the aid of Mr. Ravenstein. The testimony of travellers on the subject of these ravages is abundant. Cameron speaks of as many as fifteen villages in Urua being destroyed to make up a gang of fifty women. General Gordon's estimate is that two-thirds of the population of a large part of the Egyptian Sudan had been swept off. The attack on the market people of Nyangwe, as described by Livingstone, was the commencement of the destruction of some of the most promising races in Africa. At a meeting of the Anti-slavery Society in December last, Mr. Felkin, of the Church Missionary Society, gave an appalling account of the treatment of chiefs in the Sudan. "Another way," he writes, "to inspire fear, is to take two or three of the head men of a tribe, and, having mutilated them, to bury them alive up to their necks in the sand, with their

[illegible]

[illegible]

[illegible]

a new range of possibilities. But for the improved methods of building with steel plates, and the lightness of the high-pressure engines which had begun to be available, the task could hardly have been accomplished.

The discovery was then made by the help of the steamer, that from the upper end of the rapids to the north end of Lake Nyassa, there was a clear and straight course of navigation for four hundred miles—a hundred miles by river, and three hundred by the lake. From some mistake about the deviation of the compass, the maps were drawn so as to indicate that the north end of the lake lay rather toward the east coast of Africa. The idea, then, was to find a route from the north end to the Zanzibar coast—the quest for which may be said to have led to Captain Elton's fatal expedition. It was not without considerable research that I was able to eliminate an error of 120 miles, and satisfy myself that the north end of the lake really pointed towards Lake Tanganyika, and had confidence to construct a map showing the distance from Kambwe Lagoon on Lake Nyassa, to Pambete, on Lake Tanganyika, to be 177 miles over a plateau 5,000 feet above the sea-level, and to direct the survey of a road along that line. The survey was accordingly made by Mr. Stewart, C.E., and a road laid out about 210 miles in length, including windings, which is now being constructed. I am happy to say that we have just heard that a steam vessel in 400 sections has gone forward to be conveyed by this route, for the London Missionary Society, to Lake Tanganyika.

There will be in this way easy access to the centre of the continent. The route may be described thus:—From the mouth of the Zambezi, by that river and the Shiré, the direct distance is 200 miles, or, with windings, 300. The voyage is made by the *Lady Nyassa*, a small saloon steamer, in about a week to Katunga. The Zambezi is shallow and broad, passing through an alluvial plain. On the Shiré, where the channel is deeper, a rich valley, 15 to 20 miles wide, is bordered on the left bank by mountains, rising in some parts from 4,000 to 7,000 feet. (At present, from the want of means of transport along the coast, the route taken is by the Qua Qua river, from Kilimani to Mazaro, which involves a portage at Mazaro to reach the Zambezi). At Katunga, a 10-foot road past the rapids of the Shire, gradually rises for 35 miles to Mandala and Blantyre, attaining a height of 3,000 feet, and then descends to the upper Shire at Matope, 30 miles distant, at a level

of 1,400 feet. Goods are carried in about four days by porters supplied by the Makololo chief, Chipitula. From this point the steamer *Ilala* sails by Bandawe to Karonga, at the head of Lake Nyassa, occupying about a week, anchoring every night. The road hence to Tanganyika ascends through the Chunga country at a pretty regular slope of 1 in 33, up to the height of 4,100 feet on the great plateau, which extends many hundreds of miles to the west and south. Two miles from Malwamiu there has been formed a Free Church Mission Station, 40 miles along the road from Lake Nyassa. From this station to the proposed station of the London Missionary Society at Zombe's is 150 or 160 miles. Up to this point there are found cattle and sheep all along, and it is hoped that waggons can be used. At Zombe's the tsetse fly is found, and from this to the Lake Tanganyika, about 14 miles distant, the traffic must be made by portage. A better gradient might be obtained by making the terminus, if required, some distance along the lake in place of taking it directly to the nearest bay. It is expected that the steamer of the London Missionary Society will traverse Lake Tanganyika, from its southern to its northern extremity, in about a week, anchoring each night.

"This," says Mr. Stewart, "will be the completion of the water route to the lake region, a route of fully 1,400 miles in a nearly straight line, with only 275 miles of land carriage throughout the whole of it"—a route, I may add, from the mouth of the Shiré northwards, explored and opened up throughout by British subjects.

It is an interesting question whether the Lake Muta Nzige can be reached by water from Lake Tanganyika. If Stanley's calculation as to the level of the former lake be accepted, the fall on the river Ruanda, which flows into Lake Tanganyika from the north, and is supposed to flow from the Muta Nzige, would be too great to admit of navigation.

Connected with this Lake route which we have described, there are certain bye routes which we may here notice shortly. From its confluence with the Shiré up to the Karoubassa Rapids, the channel of the Zambezi is broad and shallow in many parts—so much so, that the traveller Serpa Pinto considers the Shiré preferable as a trade route, though involving a portage of 90 miles to Tete, the chief Portuguese settlement. Livingstone, however, took the *Ma Robert*, his steam launch, up the Zambezi in time of flood, and found only a three-knot current where it was most rapid. Quite recently the steam launch of the African Lakes Company

made the same voyage in ten days. The Karoabassa Rapids extend 40 miles, and cannot be passed. Above them for 265 miles to Kariba Gorge there is a clear channel for shallow-draught steamers, the river declining about one foot per mile. About 30 miles below this gorge the Kafue enters from the west, and Serpa Pinto states from native report that it is similarly navigable for 230 miles westwards to Kayingas or Caicuo's Town, an important trading station. From Kayingas a portage of 160 miles brings you to Lialui, the capital of the Barotse empire, on the upper waters of the Zambezi, which are also navigable.

There is another bye-route which may be important: the road between the Lakes Nyassa and Tanganyika, now being constructed, crosses the most remote head-waters of the Congo, called here Chambeze, at a point only 675 feet above the level Livingstone assigns to Lake Bangweolo. By transporting the sections of a steam launch some 80 or 100 miles across the plateau, it might be put together on the banks of the Chambeze, and could steam not only to Lake Bangweolo, but onwards to Lake Moero, as the fall betwixt the lakes is little more than one foot per mile.

Before leaving this part of the continent, I may be allowed a few words as to the conditions on which traffic is conducted by these routes. The Lisbon Government, in 1877, issued a liberal tariff for the province of Mozambique—of which I print in the Appendix an abstract furnished to me by the late Viscount Duprat, Consul-General in London, which, with alterations made from time to time, which are inconvenient, is in force now.

With a liberal tariff, a transit duty of 3 per cent., and with the opening of the coasting trade, commerce ought to progress; but there are two things which suggest extreme caution in taking any measures involving considerable outlay. In the first place, the tariff is enjoyed only by the good-will of the Portuguese, is not confirmed by treaty, and may be withdrawn at any time. Another difficulty is that the Portuguese use their African colonies as convict settlements, which are somewhat loosely managed. The convicts are allowed to scatter themselves over the continent, and when complaints are made of their outrages, the apology is that they are out of Portuguese control. They, and their half-caste offspring, are also a troublesome element of the population about the settlements. In Livingstone's time there was a half-caste of the name of Bonga, a scourge on the river Zambezi by his piracies. Mariano, another of them, swept the whole valley of the Shiré with

fire and sword in the interests of the slave trade. Shortly before the new tariff was issued, this same Mariano—called Matakenye by the natives—re-established himself at the mouth of the Shiré, and has been trying to oust Chipitula and the other Makololo chiefs, who, although certainly no perfect rulers, have saved the valley both from the Mangone or Zulu marauders, and also from the Portuguese half-castes. There has lately arisen a demand for labour for the French colony of Réunion, as there was when the valley was swept by Mariano before: and the governor of Mozambique, stimulated perhaps by his unruly subjects, paid a patronising visit to Mariano, and there was a general outcry to clear out the Makololo. The home Government superseded this governor, but Mariano remains there, watching till the Makololo run out of ammunition, and actually threatened to close the river against the British, because he had heard that a visitor had made a present of a gun to the Makololo chief, Chipitula. In strange inconsistency with this, there is a porteria, or arrangement, by which the natives are brought to Ibo, on the Mozambique coast, to be then shipped on board French vessels for these colonies. One of the Makololo chiefs, Ramakukan, it is reported, put a lot of natives into slave sticks, sent them to Ibo, and was at once supplied with guns and powder. The question suggests itself, why the Portuguese should not send their convicts to their Island of St. Thomas, as France does to New Caledonia, or England did to Norfolk Island, and thus rid the continent of so great a plague. Secondly, one may well ask why a man must become a slave dealer before he can get guns or ammunition to protect himself. Upon the East Coast of Africa—from which the waterway of the lakes is at a distance of from 400 to 600 miles—the Government of Portugal has not only prohibited the slave trade, but abolished the status of slavery; and it is much to be regretted that these intentions are so badly carried out. The Seeyid of Zanzibar has also prohibited the slave trade, but has equal difficulty in carrying out his policy. If we are to accept Mr. Hutley's statement at a recent Anti-slavery Meeting, 10,000 are brought annually across Lake Tanganyika, and as many taken to Pemba; while it is estimated that 40,000 more are exported towards the Persian Gulf. At the present time the number brought from the Nyassa district is very large, probably exceeding Livingstone's estimate of 20,000 per annum.

The Upper Nile.

The second great water-way leading to Central Africa which we notice is the Nile. The river is navigable for small vessels for a distance of 700 miles from the Mediterranean, where the navigation is interrupted by the first cataract. Thence, for a distance of nearly 600 miles to Khartum, there are five successive falls or rapids. This, with the great bend of the river, which lengthens its course, led to the survey of a railway from Assuan to Shendi, near Khartum, of which only a few miles have been constructed. The estimated cost was three to four millions sterling. Mr. Fowler also submitted plans for passing the rapids of the Lower Nile by means of locks, which have not been carried out.

Recently the idea of obtaining access to the Upper Nile by way of Suakin, on the Red Sea, has found favour. General Gordon regards this as the proper way of approach to the Egyptian Sudan, and the present expeditionary force has gone forward to Suakin accordingly. A line of swift steamers now connects this country with the coasts of the Red Sea, and can set down the voyager at Suakin within 250 miles in direct distance to a bend of the Nile at Berber. The present camel route between these points passes through a desert country somewhat broken by rocky ridges. Mr. Felkin, who recently passed that way *en route* for the Church Missionary Society's Mission at Uganda in a medical capacity, says there are no engineering difficulties in the way of forming a railway, except a few miles of shifting sands, for which a detour must be made. The length of the line would be about 280 miles. The country is somewhat similar to the district in Namaqualand, through which the narrow-gauge railway to the copper mines is carried. As that line, which is worked by locomotives, was made at an expense of £2,000 per mile, my impression is that a line from Suakin is by no means a chimerical project. From Berber the alluvial valley of the Upper Nile extends southwards for a direct distance of 900 miles without any break in the navigation except a rapid called the Sixth Cataract, which can be passed. At Khartum, which is above this cataract, the river is 1,240 feet above the sea, according to careful surveys made by the railway engineers. At Lado, on the White Nile, 1,000 miles higher up, the river is 1,526 feet, so that the fall is about 4 inches per mile and the current generally about 2 knots an hour. The channel is deep, but in some parts narrow. From Khartum up

"Gessi Pasha," he states, "writes regarding the Bahr-el-Ghazal province:—'The cotton grown there is superior in fineness, softness, and length of staple, to that of America and Lower Egypt.' 'It would be also easy to procure 10,000 cantars of caoutchouc yearly, worth about 1,800,000 francs (£72,000), whilst the expense would not exceed from 80,000 to 100,000 francs (£3,000 to £4,000).' 'Copal, palm oil, arrowroot, incense, honey, and wax, are procurable in large quantities; and any amount of nut oil, which would be of use to the steamers, though not of commercial value at present in Europe, on account of the cost of transport.'"

So recently as when Schweinfurth visited the Upper Nile, there was a large population; and his description of the manners of the various tribes was instructive and amusing. But even in 1877, Colonel Gordon writes that two-thirds of the population of some districts had been swept away by the slave trade. The estimated number of slaves exported reaches annually 40,000, and the usual calculation is that at least ten times that number are actually lost to the country in the process of capturing and driving them. The Dinka, Shilluk, and other tribes of the Nile valley, have had their tribal organisation broken up, and, by the most recent intelligence, this extends to the Mombuttus and Nyams, further to the south-west, on the watershed of the Welle. As regards these disorganised races, Schweinfurth strongly recommends that the children should be gathered into refuges. There can be no doubt that races crushed as they have been will be now more amenable than ever to kindly and civilising influences. What the population of these Upper Nile provinces of Egypt may be now it is difficult to say—it was some time ago vaguely estimated at about 11 millions.

We now turn to the equatorial province, where the conditions are somewhat different. Towards Gondokoro, or Lado—which has taken the place of the older town—mountains, reaching 4,000 feet in height, approach within 50 miles of the river on the right bank, and the hills close in to 8 miles on the left. The navigation now becomes difficult, until it is entirely stopped by a rise in the general level of the country. Here the Fola rapids extend about two miles, and are quite impassable. At Dufli, immediately above these, navigation recommences, and is continuous to the southern end of Lake Albert. The first part is over broad reaches of the river, the banks being unapproachable from the growth of the papyrus and other aquatic plants, and the current is almost imperceptible, the

fall being only one inch per mile. A fine undulating country extends to right and left, gradually rising southward to a height of 4,000 feet above the sea-level—the commencement of the great plateau which extends nearly to the Zambezi, and in which the great lakes are imbedded. This upper country is healthy for Europeans, and the slave trade has been kept down by Dr. Emin Bey, an Austrian. The Nile flows from the eastward into the south end of Lake Albert, and is the boundary of the Egyptian territory. The navigation is stopped by the Murchison Falls at the distance of 18 miles. There are then rapids for 70 miles to Foweira, whence the Nile is navigable to Ripon Falls at Lake Victoria; but it is to be hoped that our countryman Mr. Thomson will find an easier waterway to that lake from the Zanzibar coast. Lake Albert is 140 miles long and 50 miles broad, and is [illegible] above the sea-level, the lake Muta Nzige, to the south [illegible] a rough estimate of Stanley, 3,200 feet above the sea, showing that these lakes cannot communicate by water.

The steam navigation on the Upper Nile was commenced by the Egyptians before Gordon's arrival. In 1877 he had placed [illegible] steam launches on the waters, some of 60 tons capacity, and had [illegible] them in sections to the river above Dufli, [illegible] some of them of 120 tons. At [illegible] Nubians for this voyage every three months, [illegible] to Magungo, on Lake Albert.

The [illegible] approximately an itinerary of a journey [illegible] on the Red Sea, to Magungo, on Lake Albert: [illegible] Berber, 250 miles, by camel in [illegible] Khartoum, say 200 miles, by steamer in [illegible] and Kegeli, a distance of 1,026 miles; [illegible] Berber, 13 miles, by native boat [illegible] Beniben to Kiri, 28 miles [illegible] Kiri to Dufli, 85 miles by land, [illegible] From Dufli to Magungo [illegible] The distance from Suakim to Lake Albert is thus 1,830 miles by water. [illegible] voyage is extended to the southern end of Lake Albert, the whole distance would be about 1,800 miles. Steamers have been sent with some difficulty up to the Ripon Falls, and it is probable that by some skill in removing obstructions in the river the voyage might be reduced to 20 or 30 miles. The return voyage down the Nile is made in half the time.

At the watershed, between the Nile basin and the Welle, the land rises to a height of 2,900 feet. The River Welle was found by Schweinfurth to be a stream of considerable importance. It seems now to be settled that it is the same as the Shari river, which flows into Lake Tsad, which would give it a course of 1,200 miles. In the dry season it is about half-a-mile wide as it enters Lake Tsad, and Lake Tsad is then shallow, and about 10,000 square miles in extent; but when the river swells, in the rainy season in August, it gradually gains in size until November, when the lake deepens to the extent of 20 or 30 feet, and becomes at least five times as large. A great flow of water is sent eastward, by the Bahr-el-Ghazal (not to be confounded with the Nile affluent of the same name), which reaches to a depression at the foot of the Tarso Mountains, spreading widely northwards over the desert, and disappearing by evaporation in the dry season. At the highest flood water it is also supposed to send a stream westward, by the Mayo Kebbi, into the Binue, which is an affluent of the Niger. The Niger system, however, scarcely falls within our notice, belonging, as it does, to West Africa. The distance between the Jur (an affluent of the Nile) and the Welle is not great, and suggests that route as a convenient mode of access to these countries. As the Lake Tsad is 880 feet above the sea-level, and the chief town of the Mombuttus, upon the Welle, is 2,700 feet, it is probable that the Welle or Shari is navigable throughout most of its course. At Kuka, the capital of Bornu, on Lake Tsad, there are annually collected 10,000 slaves, gathered from the surrounding countries. The slaves are marched 700 miles to Murzuk in Fezzan, and then 500 miles to the coast, and the track is everywhere marked with the bones of those who have sunk under the hardships of the way.

The Congo, or Livingstone.

We now turn to the greatest watercourse of Central Africa—the Livingstone, as it was named by its explorer, or previously, the Congo, or Zaire. So far we know little of it, except from Stanley's thrilling narrative. Four hundred years ago the Portuguese erected a pillar on the Point Padrão, marking the entrance to the Congo, and for a time they had some connection with the territory, as the name, San Salvador, the capital of the kingdom of Congo, indicates; but their occupation having been long intermitted, their claim to territorial rights has not been recognised by our Government. In this position the matter has

remained since 1856. In respect of the claims of the Portuguese, we may remark that the king of Congo, the Makoko, and other Bantu were before them; that they are now in possession; and nothing is required that an international police could not effect (see page 25). On the other hand, if some Bongas and Marianos were to ensconce themselves upon Stanley's Road, as on the Zambezi, it is by no means clear that the public opinion of the Portuguese settlements, recruited so long by convicts, would permit of the Lisbon Government dislodging them. In these circumstances, it seems hardly reasonable to expect civilized nations to acquiesce in having this great river handed over to Portugal, however much its good intentions may be respected. We have had some experience of the difficulty of keeping even the Boers to their engagements.

English and Dutch houses have been carrying on trade in the estuary, but the not unreasonable fear of the natives that they would be deprived of their trade prevented all access into the interior, until Stanley suddenly appeared and explained whence that enormous flood of water, which is said to freshen the surface of the ocean for 70 miles, had brought him.

The King of the Belgians found, in these results of the liberal enterprise of the Anglo-American press, the prospect of realizing his conception of a chain of stations across the continent, and entered with enthusiasm into the opening up of the newly discovered lands to the world. The chain of falls extending, in direct distance 140 miles, has been passed by an excellent road, cut in some places, with considerable labour and expense, out of the rocky bluffs which, in some parts, abut on the river banks. The result is that the journey from the mouth of the estuary can now be made in 20 days, to the upper reaches of the river at Stanley Pool. Along the estuary from Banana to Vivi—a distance of 115 miles—the voyage can be made by steamers of any size; from Vivi to Isangila the journey is made by road, a distance of 52 miles, thence by river in a small steamer to Manyanga, about 73 miles, and by road again, on the north side of the river, about 95 miles, to Stanley Pool. A station called Leopoldville has been formed at the end of the road, across the river on the south side. On the opposite side, M. de Brazza, an explorer of the International Society, on hearing of Stanley's discoveries, made his way from the Ogowe, which debouches on the coast about 400 miles to the north, and founded a station on the other side of the Pool, which has been called Brazzaville.

At Stanley Pool we are at the commencement of a magnificent stretch of navigable river, extending a thousand miles in a curve to the centre of the continent. Stanley's narrative is probably familiar to most here; I may recall some of his chief points bearing on the opening up of the country. He gives few soundings, but he remarks that the river can float the largest vessels that ply on the Mississippi, and that there are no snags to endanger them—which he attributes to the hard nature of the bottom. The fall from Stanley Falls to Stanley Pool is about 5 inches per mile; and the current is said to be about three knots at a point below the confluence with the Nkutu. From the time Stanley came on the main river the party were free from disease, which had tried them much on the higher reaches beyond Stanley Falls. A fresh breeze blew every day up the river, as he approached the lower parts. The shores are mostly bounded by forests, in which, among many other trees, are mentioned the teak, the oil palm, the wild date, and the gum tree; among the undergrowth are the oil berry, the black ivory nut, the ginger plant, the dragon's blood tree. Oxen and sheep are not mentioned; and the presence of the tsetse indicates that such animals cannot live—which may to some extent explain the cannibal propensities of the people. Some of the tribes build splendid galleys for war purposes, and the iron weapons they produce are of excellent finish. According to Stanley, notwithstanding this appearance of civilisation along the whole course of the river, from a short distance above Stanley Pool, and on the upper river nearly to Nyangwe, strangers are regarded only as so much food brought within their reach. Some, however, of the races were found hospitable and friendly.

On the lower part of the river many boats were met, with native traders on board; but certain limits, within which each tribe carries its goods, seem to be strictly maintained. It is conceivable that the opposition to Stanley may have been partly occasioned by his breaking these trade rules, and to be compared with the difficulties any one would find who tried to cross Europe in defiance of the Douaniers. It is probable, too, that some rumour of the ravages of the Arabs at Nyangwe may have reached this part of the river and created hostility. Stanley estimates that it takes five years for goods to be taken well up the river at present.

It is remarkable how superior races have in many regions become addicted to the practice of cannibalism, in some places a perverted application, mayhap, of the doctrine of the survival of the

fittest; but in Manyema and other places taking the form of ghoulish feasts. It seems to arise from the craving for animal food, which appears to be strong in the African climate. In the Fiji Islands it was remarkable how the introduction of the pig assisted in the abolition of the practice; and it may not be amiss to remark that the introduction of beef and mutton into cargoes on the Livingstone might lead to a somewhat similar result. The health of Europeans on Lake Nyassa greatly improved when regular supplies of such food came to be brought in by the African Lakes Company.

I shall mention now the tributaries of the Livingstone, of which something is now known from other sources. Those on the north side are of less importance, as is shown by the fact of the Congo only rising 2 feet when they are in flood—while it attains 9 feet when the flood is from the south. The Alima is that by which De Brazza hopes to make a practicable trade route from the Ogowé to the Congo; but as there is a distance of 500 miles from the port where ocean steamers can discharge, it is not obvious what advantage there is over Stanley's easy road. The account De Brazza gave to the Paris Geographical Society of his interviews with the natives is curious. His first object on reaching the banks of the great river was to establish peaceful relations with the Apfuru and other tribes of the Ubanji nation. The principal of these were the Alhialumo (sailors of the Congo), who are born, live, and die with their families on board of the fine canoes, in which they carry on a trade in ivory and other goods between the Upper Alima and Stanley Pool. With these he had first to deal. He addressed himself to Ngampey, their chief, who seemed inclined to be friendly. "Choose," M. de Brazza said, "between the cartridge and the flag I send you: one will be the sign of war without mercy, the other the symbol of a peace as profitable to you as to us." That an African interpreter would translate literally this speech, or others made to Makoko, would be contrary to all experience.

Of the Bangala and the Ukere nothing is known. The Aruwini was thought by Stanley to receive the waters of the Welle, but quite recently it is believed that its head waters have been described from native report, with an extensive lake through which it passes. It would appear to drain the northern slopes of the mountains west of Lake Albert. Judging from the size of the equatorial affluents that pour into the Congo from the east, the

rainfall on these mountains must be very great. The Lowwa is 1,000 yards wide, the Mburra is 600, while the course of neither can much exceed 200 miles in length; and it is not surprising that the Aruwini is described as 2,000 yards in width where it joins the main river, and that it is said to be navigable for several hundred miles.

Of the large affluents on the south side of the Congo, the western branch of the Nkutu is well known as the Quango. The Portuguese travellers, Capello and Ivens, examined the upper portion, which is too much encumbered with falls for navigation. From the lowest fall, called Kikongi, Von Mechow attempted to descend in a boat 300 miles to the confluence with the Congo, but his boatmen compelled him to return on account of a cannibal tribe he was approaching. Several German travellers—Buchner, Pogge, and Wissmann—have been exploring the other southern affluents of the Congo. From their information it appears that the Nkutu receives the Kasai and the other rivers to the 23° lon. The Ikelemba, which pours a flood of sea-green water into the Congo 1,500 yards in width, seems to draw its great supply from the forest lands directly under the equator, where the rains extend to both parts of the year. These and other rivers are probably navigable, perhaps with a break corresponding with Stanley Falls. The Sankuru, there called Lubilash, was found, at a distance of 500 miles from the Congo, to be of the same size as the Elbe (about 500 feet wide), and as the fall is little more than a foot per mile, it is probably navigable from the Congo upwards.

About the fifth parallel, south latitude, a plateau of about 2,000 feet above the level of the sea bounds on the south the dense forests through which these rivers flow northwards. It is thickly peopled by most interesting tribes. Here is part of the most recent intelligence brought by Wissmann. He came through the country of the Basonge, in the very heart of the continent:—"They lived in beautiful villages, miles in length, cultivated the land, and excelled in the manufacture of cloth, pottery, iron articles, and wood carving. To the east of these tribes, however, I found that, in consequence of a recent inroad of the Arabs of Nyangwe, the villages had been deserted. The Basonge have never yet seen an Arab, nor heard the report of a gun, but I am afraid their fate is sealed."

To return to the main river, above Stanley Falls, which extend about 62 miles, or if the two lower can be passed about 8 miles, there is a clear course of about 220 miles, when the river is again

broken by a fall 50 miles below Nyangwe. There is another fall about 50 miles above Nyangwe, and just above it an affluent called the Luasse, which is navigable for swift steam launches well on towards Lake Tanganyika. The main river from Lake Moero to this point declines at the rate of about 4 feet per mile, and is probably not navigable. Lakes Bangweolo and Moero are probably more accessible by the Nyassa Lake route. The country to the west of these lakes was partly explored by Cameron, and is visited by slavers both from the east and the west of the continent. Keith Johnston thus describes these countries:—"In taking a general survey of the country, from the Tanganyika to the west coast, it is evident that it is one of enormous natural wealth. The oil palm flourishes all over the broad valley of the Lualaba to an elevation of 2,600 feet above the sea; cotton, coffee, nutmegs, pepper, tobacco, sesamum, and india-rubber are among the vegetable products which grow wild; and wherever the Arabs have penetrated from the east coast they have successfully introduced the cultivation of rice, wheat, onions, and fruit trees. Of metals there are iron and copper and cinnabar in abundance; silver and gold are also known in Urua. The blot upon this fair country is the slave trade, which is carried on to a great extent to supply those countries which have already had their population depleted by the old coast trade. The chiefs like Kasongo and Matazafa are utterly and entirely irresponsible, and would give a man leave for the present of two or three guns to go and destroy as many villages as he could for slaves."

General Observations.

I would desire now to lay before you a few general observations on practical work, chiefly gained from experience regarding the lake district. With regard to the probability of getting any produce out of these regions when ivory is exhausted, the present almost prohibitive rates of carriage give no criterion as to what may result if the rates are reduced. This will be a gradual process—ivory, with other articles, will have to be the cargoes for a time, but it will be found that many products will come to have a place, and scientific investigation of the different districts should be made. India-rubber yielding plants are very widely distributed, and, next to ivory, can afford a large freight.

The disposition of the natives to work is an important element of progress. Many of the interior tribes show considerable skill,

both in handicraft and agriculture—for example, the working of iron seems almost universal. A great deal depends on how they are approached at first. Livingstone recommended that to a new tribe a preliminary visit should be paid; if all went well, it would be found on a second visit that considerable advance had been made in the interval in gaining their confidence. For instance, in preparing to make the road between the lakes—Nyassa and Tanganyika—it was not until after the second or third visit that the Chungus would give much aid in exploration or work. By accounts just received, they were working with a will at a wage in cloth, costing about 1s. 10d. per week; and the undertaking was well advanced. Road making, which will be required on the different portages described in connection with these routes, is a very good training for steady work, and the natives seem fond of it. I may mention that the ten-foot road past the rapids of the Shiré was made at a cost of £7 per mile, paid in cloth, for native labour. There being some danger of the tsetse fly, this road has not been made for waggon traffic. The road between the lakes, also 10 feet wide, but intended for waggon traffic, is expected to be made for £20 per mile—the half of which is for native labour, and the other half for salaries and such simple bridges, etc., as are required. The people here never saw an Arab, much less a European, till 1878. Latterly, slave hunters have been in their neighbourhood, but there is every reason to believe that the presence of the engineer, the trader, and the missionary, will save them. The next stage might be to get them to make plantations of commercial articles, such as the *ficus elastica*, which is indigenous. Their agricultural skill was much admired by Thomson and other travellers.

To sum up, I have thus shown that in the six million square miles of Central Africa there are included three main lines of water communication actually available, each reaching directly into the centre of the continent, and that intercommunication could be established between them without difficulty. Besides these, there are side water-ways—on which shallow-draught steamers could easily ply—perhaps equal in length to the main water-ways, so that these water highways and bye-ways may extend nearly to 10,000 miles. On the Lake route and the Zambezi there are already Mission Stations about every 150 miles—those on the Zambezi being Roman Catholic, in course of being established—and there is also a Belgian International Station, with a steam launch on Lake

Tanganyika. Trade is being successfully conducted in the cautious way that the circumstances require. Coal is being found here and there in the country. On the Upper Nile there were three Roman Catholic Stations, but in consequence of present disturbances it is believed that these are reduced to one. A moderate trade was being carried on previous to the late complications. Coal has not yet been found in these countries, and would be essential to any considerable traffic—wood being scarce. It might be supplied by a Suakin-Berber Railway. On the Livingstone, Mission Stations are established all the way on the estuary, and up to Stanley Pool; at Stanley Pool the missionaries are waiting till the way is opened up for further advance. Stanley himself has formed a line of Trading Stations up to the Pool, also at the mouth of the Nkutu. He has four steamers—two on the estuary, one to connect the two sections of the road, and one on the Upper River. Wood for fuel is here abundant everywhere.

An interesting statement has been made by Sir Bartle Frere in a recent periodical, showing that the working of the Act passed in 1843 for the abolition of slavery, by which nine millions of slaves in India recovered their freedom, was aided by the great public works, the construction of which dates from the same period. He states "that the engineer and his contracts have been, if unconsciously, yet very effectually, as potent agents in the emancipation of the Hindoo serf or slave as the legislator, the administrator, or the philanthropist." There is, however, in Africa a primary difficulty, in this respect that there is neither the legislator nor the administrator. Not but that there are unwritten customs which have the force of laws. Indeed, some of the institutions of the Bantu races have a considerable resemblance to those of our Saxon or Scandinavian forefathers; but there is an alien and hostile element that is destroying all these germs of progress. The engineer and the trader, with the missionary, may do much to keep the slave trade in check, or even to uproot it. Our cruisers can also help in the same cause. But, as I have already explained, the fact of there being practically irresistible force against order in the hands of slave hunters, creates a state of things that is without precedent. The rising price of slaves and ivory tends to increase these evils. Taking the lowest view, there is some danger of the hopes that are entertained of the value of new markets in Africa being frustrated from the industrial population being destroyed and warlike tribes only being left.

There is, therefore, important work for the diplomatist and the statesman in keeping open access to the interior by the river entrances we have described, and in applying such checks to the slave trade as international law can be made to afford. The principles that underlie the decision given at the Geneva Conference may in some way be applicable to such states as exercise inadequate vigilance to prevent the departure of slave-hunting caravans, or to secure the punishment of those who may be proved to be engaged in slave hunting on their return. The same principle may be applied to want of vigilance in preventing the departure of slave ships.

In a paper first read before the British Association in this city seven years ago, and afterwards published, the writer ventured to suggest that an armed police force, moving rapidly in steam launches by the water-ways, might serve as an efficient check to slave hunting. As a centre of its operations the neighbourhood of Lake Albert might be selected, and from that position a line of depots might be formed in a north-westerly direction on the water-shed between the Nile and the Welle, and southward on that between the Zambezi and Congo affluents, and between the Lakes Tanganyika and Nyassa. By these, communications could be kept up with the police force on the water-ways, and they might serve also as sanitaria. If countries having no desire for territorial acquisitions in Central Africa, but which have otherwise great interest in its commerce, civilisation, and progress, were to take the initiative in such an enterprise, the circumstance that Portugal and Zanzibar are understood to be negotiating a treaty, of which one clause provides for the extradition of slave hunters, would seem to indicate that the Coast Powers of Africa would co-operate. Limited contributions from the engaging powers would meet the expense of such a police, toward which the United States might not be unwilling to contribute from the balance remaining to its credit of the Geneva award. The question as to the slave trade being piracy, is at present in an awkward position of uncertainty; it was proposed, we believe, to declare it so at the late Berlin Congress, had not our envoys objected. Surely something can be done to settle this great question now.

Another question of vast importance pressing for solution is that of the supply of arms and ammunition to the natives. The present system, by which convicts, and the scum of Mahommedan countries, and slave-hunting chiefs, can freely obtain offensive weapons,

while a cordon is kept by the Coast powers against a supply of defensive arms, is not satisfactory. An armed anti-slavery police could reverse all this. There is now sufficient knowledge of these countries to permit of the right sort of native recruits being obtained. The granting of arms more generally might be also made to contribute to the advancement of civilisation, if arms and ammunition were sold to industrial tribes that have been more or less civilised, who would use them for defensive purposes.

In the index map I have shown the boundaries of the regions accessible from the inland waters, as distinguished from those more readily reached from the coast. In dealing with this vast inner region of some four millions of square miles internationally, there can hardly be said to be any European complication possible, and the same may be said of the Nile and Congo approaches. On the Zambezi a passing toll of 3 per cent. should satisfy the Portuguese. The suppression of the slave trade in these regions would be a fitting conclusion to the great measures by which two millions of these races became citizens of the British Colonies, and seven millions of citizens were added to the United States.

An increase of general intelligence on geographical and ethnological subjects would undoubtedly be of great service, both in the formation of sound public opinion upon such subjects as I have been considering—which might be an assistance and support to the Government—and also in the intelligent direction of mercantile enterprise. This we have hardly prosecuted lately with the energy of some other nations. By the combination of all the means suggested we may, I trust, reach the result that, instead of the sale of the man, there may be the sale of what he produces in his own land—which is the end of the slave trade.

APPENDIX.

"Portugal's African Colonies.

"The Government, after duly considering the recent development that has taken place in Africa, and with a view of enabling our Colonies to accompany the onward movement in the march of progress, and occupy the prominent place that of right belongs to them, has established a new tariff of customs at Mozambique, the result of which will, of course, be to attract commerce to that

province and open all ports to national as well as foreign trade. The decree also permits commerce to be carried on along the coast under a foreign flag."

"The new tariff of customs duties for the province of Mozambique is as follows:—

"Import Duties.

	Reis.
Butter, European or Indian, per kil., ...	80
Gunpowder, ...	100
Guns, gun barrels, and revolvers, ...	500
Hoes, ...	60
Liquors, distilled, per litre, ...	90
Do. fermented, ...	20
Metals unwrought or wrought, 6 per cent. *ad valorem*, excepting iron.	
Molasses, per litre, ...	90
Oil, olive, ...	20
Pistols, each, ...	500
Ships (new or seaworthy), to be registered as Portuguese vessels, 5 per cent. *ad valorem*.	
Vessels (condemned as unseaworthy) to be sold, 4 per cent. *ad valorem*.	
Sugar, per kil., ...	30
Tea, per kil., ...	60
Tobacco, unmanufactured, ...	200
Do. (manufactured), cigars, ...	600
Do. other lots, ...	400
Wine, in barrels or bottles, per litre, ...	40
Woollens, cotton, raw white, including handkerchiefs, per kil., ...	90
Woollens, cotton, stamped, dyed, ...	60
Do. open or transparent, such as lace, silk, &c., 10 per cent. *ad valorem*.	
All other goods not enumerated, duty free.	

"Export Duties.

Cowrie shells, ...	4 per cent.	*ad valorem*.
Gums, ...	2	do.
India rubber, ...	4	do.
Ivory, ...	6	do.
Orchilla weed, ...	1	do.
Seeds of all kinds.	1	do.
Skins and hides, ...	2	do.
Wax, ...	4	do.
All other articles not enumerated, duty free.		

"This decree was favourably received by all the Portuguese press, and is generally considered as an essential basis for the future development of the province of Mozambique."

"Art. 70 of the new Mozambique Customs Tariff—The transit through the Custom Houses, mentioned in Art. 11*, of merchandise coming from places outside the province, and destined, either by land or water, for foreign countries bordering on the north and south of Portuguese territories, is permitted, and also merchandise for places situated beyond the point of confluence of the Chire and Zambezi, on payment of a sole duty of 3 per cent. *ad valorem.*"

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* These Custom Houses are Delagoa Bay, Inhambane, Sofala, Quilimane, Mozambique; also one at the confluence of the Zambezi and Shiré (Chire), and one near Cape Delgado. The duty on guns has been raised to 3 dols., and there have been other changes, especially on imports. In 1880 the import duty on shirting was equal to 17½ per cent., on drills 7½ per cent., and on scarves 9 per cent. *ad valorem*. These are the provincial duties, but to the inner waters the transit duty has been always 3 per cent. J. S.

ARABIA
Sonrhaisana
Loheia
Hodeida
Mocha
Aden
Mokalla
C. Guardafui
Bas Hafun
Zeila
Berbera
Harar
Melmil
Dallo
Imi
Karanle
Eaf
Bad
Shabele
Logh
Bardera
Mukdishu
Merka
Brava
Equator
INDIAN OCEAN
ATLANTIC OCEAN
R. Niger
R. Jub
Kisimayu
St Thom
Pata
Malinde
Rabai, Kimulatini & Ribe
Mombasa
Pemba I.
Zanzibar, Mbweni & Kiungani
Dar es Salam
Kilwa
Lindi
Comoro
Mayotta
C. Amber
Nosi Be
Ibo
Mozambik
Angoshe R.
Majunga
Antongil B.
Ste Marie
Antananarivo
Tamatave
Mahanuro
Mozambik Channel
MADAGASCAR
SLAVE TRAD
EQUAT
AFR
illustrative o
J. STEVE
Scale 1:23,0
Tracks of
Slave-Hu
Principal
by Slave
the Coast

XVII.—*On a New Apparatus for Recording the Time of Occurrence, the Duration, and the Nature and Magnitude of the Motions in an Earthquake.* By THOMAS GRAY, B.Sc., F.R.S.E.

[Read to the Society, 28th February, 1883.]

THE apparatus described in the present paper has been designed for the purpose of recording the time of occurrence, the duration, and the nature and magnitude of the motions in an earthquake. This apparatus has been made by Mr. James White, Glasgow, and is to be used by Prof. Milne, at Tokio, Japan, in the investigations which are being carried out by him as one of the committee appointed by the British Association for the investigation of the earthquake phenomena of Japan.

An earthquake generally consists of a considerable number of separate to-and-fro movements of a part of the earth's surface. These movements are irregular in magnitude, to some extent irregular in period during any one earthquake, and vary very much as to period, duration, and magnitude in different earthquakes. From past experience in Japan, we infer that this instrument may have to record motions varying from one-tenth of a millimetre to ten millimetres in amplitude, and from one-fifth of a second to something near one second in period; while the duration of the earthquake may vary from half-a-minute to about four minutes.

In order to determine the amount of movement, it is found convenient to record three rectangular components of it—two horizontal and one vertical. The horizontal components are recorded by means of the two pendulums, P, Fig. 1, Plate VI. Each of these pendulums consists of a hollow brass cylinder, C, filled with lead, and suspended by a silk thread. The cylinder, C, is held deflected from the position in which it would hang with its centre of gravity vertically under the point of suspension by means of a thin tube, t. This tube terminates at one end in a sharp vertical knife edge. One of these

tubes is continued by a long, very light index of aluminium foil; while a similar index is attached to the tube of the other pendulum close to the knife edge, and with its length at right angles to that of the tube. The knife edge rests in a flat V, cut in a hard steel plate, and the point of suspension is adjusted by means of screw adjustments, capable of giving motion in three directions at right angles to each other, until it is very nearly vertically above the knife edge, and at such a height that the knife edge bears along all its length. The points of suspension are so adjusted that the planes through the axes of the tubes, t, and the suspending threads are at right angles to each other. The indices are thus parallel to each other, and they are arranged to be in a horizontal plane.

The vertical component of the motion is recorded by means of the mass, M, supported on the end of the lever, l, by means of the spring, S, and actuating the vertical index, i. The lever, l, is firmly attached to the cross bar, b, which is sharpened on its upper side to a knife edge. The sharpened edge of b rests in a flat V-shaped groove formed on the under side of a steel plate, while the spring is attached to the lever by links working round knife edges. The mass, M, is considerably further from the knife edge than the spring, S, the reason for this being that a moderately long period of free vibration can thus be obtained without an inconveniently long spring. The period of free vibration is lengthened to some extent by placing the point of attachment of the spring a little below the line joining the knife edge and the centre of inertia of the mass, M, and it is still more increased by a box, B, which is partly filled with mercury, and thus adds negative stability to the positive stability of the spring. The index, i, is attached at its upper end to the box, B, which is mounted on a long horizontal axis, and supported at one end by the lever, l. In order to give rigidity to the index, i, without making it massive, it is made of a very thin tube of aluminium, which is prevented from bending sideways by fine silk threads attached to its point and to light cross bars of aluminium at its upper end. The threads are kept stretched by a light but stiff spiral spring which presses against the top of the tube. To the point of the index a very flexible piece of aluminium foil is attached, which projects in a horizontal direction, and can be raised or lowered by a thread which passes up the centre of the tube and round a pin fixed in the end of the box, B.

These three components of the motion are written on a band of smoked paper, wound round a drum, D, which is kept continuously

rotating by a train of clockwork, W. The ends of the indices are arranged to lie on a line parallel to the axis of the drum, so that the corresponding vertical and horizontal components can be easily detected. The pressure of the points of the indices which write the horizontal components on the paper can be adjusted by means of threads attached near the ends of the indices, and passed over studs fixed in the pillar which supports the pendulums.

The clockwork, W, is driven by means of two weights acting on separate driving-wheels, one on each side of the first pinion, thus, at the same time, giving a pure couple to the pinion, preventing excessive weight on the bearings of the weight-barrels, and avoiding the necessity for maintaining power to keep the clockwork in motion during winding. The clockwork is governed by means of a governor of the form shown in section, in Fig. 2 (Plate VII.), where g is a light cylindrical box partially filled with glycerine, or some such liquid, and mounted in a vertical axis, a, which in this instrument works in jewels at top and bottom. The box, g, is geared to the clockwork by means of the pinion, p, and the crown wheel, w. The governing action is obtained by causing the liquid to come into contact with a fixed vane, v, which can be turned to different distances from the side of the box, so as to vary the speed.

The action of the apparatus is as follows:—Suppose that the earth moves in a direction at right angles to the plane of one of the deflected pendulums, then, since that pendulum is very free to move round a vertical axis, the inertia of the bob of the pendulum causes it to turn relatively to the remainder of the apparatus, and consequently the point of the index attached to it will move across the drum through a distance depending on the length of the pointer and the distance of the instantaneous axis of the bob from the knife edge. There will, however, be no motion of the other pendulum. The same is true of motions at right angles to the other pendulum, or to the lever, l, and hence if the motion be inclined to all of these, each one will indicate its own component, thus determining the nature, magnitude, and direction of the movement.

The duration of the earthquake is obtained from the known rate of motion of the drum, D, and the length of the record on the smoked paper.

The time of occurrence is obtained by means of the timepiece T, and a system of magnets and circuit-closing apparatus. The

circuit closer is shown at E, and consists of a small pendulum, the bob of which is made to turn a light metallic tube, r. The tube, r, is carried on a point resting in a conical hole in a rod rigidly attached to the framework, and it is pivotted to the pendulum by resting a point in a conical hole pierced in a small block on the end of a fine spring, so attached to the bob of the pendulum that the conical hole is under its centre of inertia. The lower end of this tube hangs in the centre of a dimple formed by capillary attraction in the surface of a cup of mercury, over a thin iron pin fixed in the bottom of the cup.

When the framework of the apparatus is slightly shaken, the point of the tube cuts into the mercury, and thus closes the circuit of the electro-magnets, e_1, e_2. The electro-magnet, e_1, attracts an armature to the end of which is attached an index, the point of which is in the same line with the ends of the indices for writing the movements on the circle. When this makes a mark on the smoked paper which shows at what part of the shock the circuit was closed. The magnet e_2, at the same time relieves a catch, and allows the weight to fall [illegible] which passes through [illegible] This shaft is provided with two [illegible] which [illegible] forward on [illegible] and thus leave [illegible] which the circuit was [illegible] through the mer- [illegible] thus [illegible]

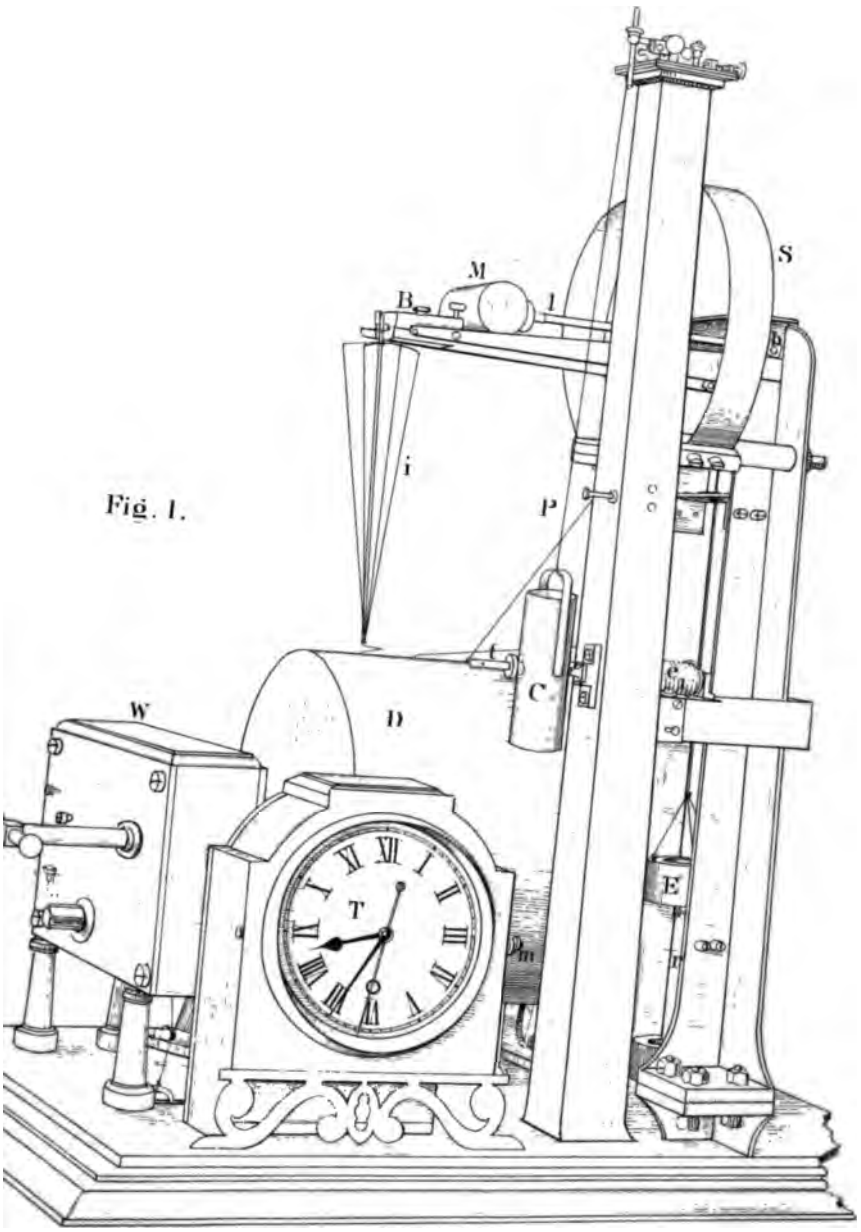
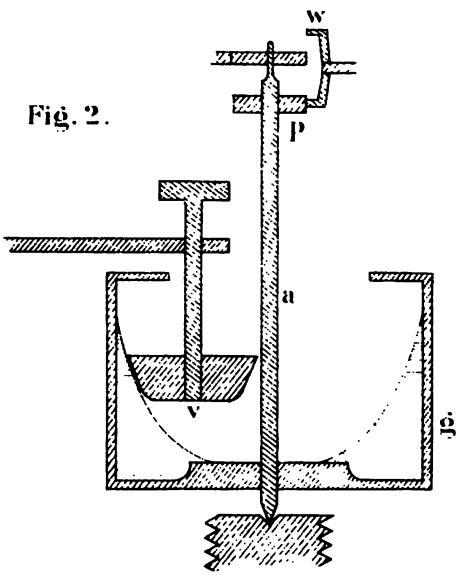


Fig. 1.

Fig. 2.



XVIII.—*The Fertilisation of Flowers.*

By Professor ALEX. S. WILSON, M.A., B.Sc., Anderson's College, Glasgow.

[Read before the Society, 11th April, 1883.]

WHY does the blossom always precede the fruit? What hinders the fruit from appearing before the flower? How does a display of flourish affect the productiveness of a tree? These are questions to which complete answers have been wanting until recent years. When the orderly succession of natural phenomena is so unvarying as that of flower and fruit, we may generally infer a causal relationship between antecedent and consequent, and, from the undeviating constancy with which blossom precedes the formation of fruit, a hidden connection of this kind might have been suspected. Familiar, however, as this order of sequence has always been, it was left to modern scientific research to explain the connection between flourish and fertility. That this relationship has been so long unexplained is, no doubt, owing to the prevalence of an exclusively æsthetic view regarding flowers, and to attention having been confined almost entirely to the economic value of fruits. At the outset, then, it may be well to point out that, so far from its being true that all fruits were made for the purpose of being eaten, many fruits are not edible, while great numbers are even poisonous. The popular idea regarding fruits is altogether inadequate to account for their existence. All fruits, however, agree in this respect, that they are provided with appliances which insure the dispersion of their seeds. Among the adaptations which facilitate the scattering of a plant's seeds, the following may be mentioned:—

1. Winged fruits and feathered seeds—suited for dispersion by the wind. Examples of this class are found in the fruits of the elm and maple, and in the seeds of the thistle and dandelion.

2. Fruits which explode when ripe, and forcibly eject their seeds—geranium, balsam, wood sorrel, *Hura crepitans.*

3. Fruits and seeds provided with hooks intended to catch hold of the fur of passing animals—burdock, bedstraw, grapple-plant.

4. Coloured and pulpy fruits. These by their colours attract birds that devour the soft parts and reject the hard, indigestible seeds, which are in this way disseminated—strawberry, rasp, bramble, rowan, rose-hip, cherry, &c.

In the fruit of every plant provision of some kind is made for the dispersion of its seeds, and every part of the fruit has its use in the economy of the plant. This is also true of the flower. A flower is a branch that has been specially modified for the production of seed. The purpose of a flower is to form seeds, and all its parts help in some way to attain this object. Flowers are not simply ornamental—they render important service to the plant in helping it to produce good seeds, and they help in this way—

1. Every flower requires to be fertilised before it can produce any seeds. Fertilisation consists in the application of the pollen or flower-dust to the stigma. The stigma is simply the top of the young seed-vessel, and is usually covered with a viscid secretion which causes the pollen to adhere to it. The pollen itself is the yellow powder produced by the stamens; it consists of grains which are in reality cells. When placed on the moist stigma, these germinate much in the same way as the spore of a fungus does, giving rise to a root-like process (the pollen-tube), that grows out from the pollen grain, penetrates into the interior of the seed-vessel, and comes in contact with the young seeds within. Soon after this has taken place an embryo appears in the seed, which is then capable of growing up into a new plant. Fertilisation is akin to the gardener's operation of grafting or budding, for the pollen-grain may be regarded as a graft reduced to a single cell.

2. The greater number of flowers possess both seed-vessel and stamens, and we might readily suppose that a flower's own pollen would suffice for its fertilisation. Self-fertilisation does, indeed, occur, but there can be no doubt that in nature it is the exception rather than the rule—being only adopted as a last resource. Provisions exist in a multitude of flowers which have for their object the prevention of self-fertilisation. In such unisexual flowers—as those of the cucumber, nettle, hemp, willow, alder, hazel, oak, and poplar—where the flower that produces the seed-vessel is destitute of stamens, self-fertilisation is, of course, impossible, and pollen must be brought to them from staminate flowers if they are to produce seeds at all. But even where both stamens

and seed-vessel coëxist in the same flower, self-fertilisation is frequently rendered impossible, either (1) from the relative position of the organs, or (2) from stigma and stamens becoming mature at different times (dichogamy), or (3) by the impotency of the flower's own pollen when applied to its stigma. Corresponding to these provisions against self-fertilisation, we find in all orders of flowering plants beautiful and often complicated contrivances for securing cross-fertilisation.

3. The researches of Mr. Darwin have put us in possession of facts which clearly demonstrate the superiority of cross-fertilisation over self-fertilisation. In flowers which were not strictly self-sterile, he found that a greater number of seeds were produced when the flower was fertilised with pollen taken from another flower than when it was fertilised with its own pollen. Not only were the crossed seeds more numerous, but they were larger, and, when sown, grew up into stronger plants than could be obtained from the seeds of flowers that had been fertilised with their own pollen. The results which he obtained in the case of *Ipomœa purpurea (Convolvulaceæ)* may be taken as typical. Ten generations of this plant were grown, and in each generation the average height of the self-fertilised plants was compared with the average of the intercrossed ones. In every instance the comparison was to the advantage of the crossed plants. The mean of the whole ten generations showed that the height of the plants obtained from the crossed seeds stood towards that of the self-fertilised ones in the ratio of 100 to 77, or as a man of six feet in height would do to one only 4 feet $8\frac{1}{4}$ inches.* Even in those flowers, then, which are able to produce seeds when fertilised with their own pollen, it is clear that cross-fertilisation, since it is attended with great advantages, must be highly desirable.

4. When we speak of cross-fertilisation, it must not be supposed that this means hybridisation, or the inoculation of a plant with pollen from a different species, but simply that it be fertilised with pollen from another individual of the same species. Where a plant produces more than one flower, an intermediate mode is possible—viz., the crossing of flowers belonging to the same individual plant. Experiments show that such limited crossing produces effects little, if any, better than self-fertilisation, and the arrangement of flowers on the stalk is often such as to prevent

* "Cross and Self-fertilisation of Plants," p. 53.

this kind of crossing. We do, however, meet with plants which have arrangements for securing self-fertilisation in the event of their failing to be crossed. Towards the end of the season, the violet produces minute flowers, which never expand and yet give rise to numerous seeds. These cleistogamic flowers are interesting as being adapted exclusively for self-fertilisation. They differ from ordinary flowers in these respects—(1) They do not open, but remain permanently in the closed condition of the bud. (2) Their petals are wanting, or are reduced to the condition of mere scales. (3) They produce only a few grains of pollen. (4) Their anthers do not dehisce, but the pollen-tubes are emitted from the pollen-grains while still contained within the anthers. (5) The stigma is wanting, the orifice of the seed-vessel being open, so that the pollen-tubes easily find their way to the young seeds within. (6) Cleistogamic flowers have no bright colours, markings, odour, or honey. Here, then, we remark a saving effected in the petals, pollen, honey, and scent, and the material thus economised avails for the production of a large number of seeds. In these flowers great numbers of self-fertilised seeds are played off against the superior vigour of crossed ones, and they furnish the violet with a safeguard against extinction in the emergency of its failing to get any of its ordinary flowers properly crossed. Species of *Oxalis*, *Lamium*, *Trifolium*, and many others, possess flowers of this kind in addition to their ordinary open flowers. The evident adaptation to self-fertilisation in these flowers leaves no room to doubt that all ordinary open flowers, whose anthers open and discharge pollen, or expose it so that it can be removed, whose stigmas are fitted for the reception of pollen, are adapted for cross-fertilisation rather than self-fertilisation. Otherwise, there would be an amount of waste and unnecessary expenditure of material, in large bright petals, honey glands, and pollen grains, quite out of keeping with the strict economy of vegetable life. Practically, then, we are warranted in concluding that all ordinary open flowers require and are adapted to be cross-fertilised.

5. Cross-fertilisation, however, implies the transference of the pollen from one flower to another of the same species, as well as its application to the precise part of the flower prepared for its reception—*i.e.*, the stigmatic surface. In nature the pollen is transported either by the wind or by insects. In a few cases water, humming-birds, or snails may be instrumental in effecting cross-fertilisation. With these exceptions, flowers admit of classification

into two divisions—(1) Wind-fertilised; (2) Insect-fertilised flowers. The wind-fertilised include grasses, rushes, sedges, nettles, docks, hop, pellitory (Urticaceæ), Poterium (Rosaceæ), bulrush *(Typha)*, and trees, such as the oak, beech, birch, elm, ash, alder, poplar, hazel, fir, and many willows. Wind-fertilised flowers produce no honey, have no smell, and are inconspicuous owing to the absence of brightly-coloured petals. In these respects they resemble cleistogamic flowers, from which, however, they may be distinguished by their being open, by their anthers producing and scattering a large quantity of light incoherent pollen, and by their highly-specialised stigmas. The floral envelopes (calyx and corolla) are either awanting or much reduced in size, so that the wind may have free access to the interior of the flower. Their stamens have long slender stalks, and are readily shaken by the wind, in order that the scattering of the pollen may be facilitated. Relatively to insect-fertilised flowers, the amount of pollen produced by the wind-fertilised ones is enormously greater. Thus, it is not uncommon to find the ground quite yellow from showers of pollen from the Scotch fir. Each pollen grain of the fir is provided with inflated wings, which make it light and easily wafted by the wind. Their stigmas are in the form of feathers or brushes, which expose a large surface to the air with the object of catching the pollen blown to them by the wind. This may easily be verified by looking at the common ryegrass in flower, when from every little spikelet will be seen hanging out on both sides beautiful feather-like stigmas, spread out as a fisherman might spread out his nets, or a sailor his canvas to catch the breeze. The finely-fringed and spirally-twisted stigmas of the common rush, too, are well worth looking at as an adaptation to wind-fertilisation. Very frequently in this class the flowers are produced before the leaves, as the foliage would interfere with the wind having easy access to the flowers. In every respect it is evident that such flowers are admirably adapted for cross-fertilisation through the agency of the wind.

6. Passing now to the second division, which is by far the larger and more interesting section, insect-fertilised flowers secrete honey or nectar for the purpose of inducing insects to visit them. Flower-frequenting insects carry the pollen from flower to flower, adhering to their bodies, and thus become agents in effecting cross-fertilisation. Very often the pollen is glutinous, or each granule may be studded with projections which cause it to adhere to the hairy covering of an insect, reminding us of the hooklets on the fruit of the bedstraw

by which the seeds are disseminated. In the orchids and asclepias the pollen grains cohere into packets, which are removed by the insect *en masse*. The stigmas of insect-fertilised flowers are of various forms, but never feathery or fringed, like those of the wind-fertilised class. The stigmatic surface secretes a sticky, viscous fluid of remarkable tenacity, intended to retain the pollen grains. The adaptation of flowers to the visits of insects, however, is by no means limited to the pollen grains and stigmas, for all parts of the flower are involved. The correlation between flowers and insects is in fact so intimate—there is such a striking correspondence between the organs and habits of these two classes of organic beings, the mechanism of flowers is often so intricate, and the contrivances for securing cross-fertilisation, through the intervention of insects, are so numerous and varied—that it will be necessary to treat of these adaptations separately.

7. Adaptations observed in the forms of flowers. The form of the flower in numerous instances is as clearly determined in relation to the species of insect frequenting it as in the wind-fertilised division the form has reference to the wind. Take, for example, the common primrose. The corolla consists of a narrow tube, with a broad, horizontal flange or rim at the top, which serves as a platform from which the insect can conveniently dip its proboscis down into the flower, and suck up the nectar which is secreted at the bottom of the tube. In a flower of this form the nectar is inaccessible to all insects except such as possess a proboscis as long as the tube of the flower.

(*a*) Regular flowers, like the primrose, which have all their parts equal, do not as a rule exhibit so much specialisation in relation to insects as irregular ones do; nevertheless, they admit of being arranged in a series according to the depth of their nectaries.—We have (1) shallow open flowers, in which the nectar can be reached by any insect however short its tongue; (2) narrow tubular flowers, whose depth does not exceed three-fourths of an inch, and where the nectar in consequence is accessible only to bees and butterflies; and (3) deep flowers with narrow tubes exceeding this length, and nectar inaccessible to bees—adapted to Lepidoptera alone (butterflies and moths). In open flowers of the first division, such as the wild rose, buttercup, or lily, there is no limitation to any particular class of insect, but the nectar is open to all comers, and the adaptation is not so obvious. No distinction is made between the visitors—flies,

bees, and moths being all equally welcome. From flowers of the second type flies are excluded. Thus the clover, comfrey, primrose, columbine, many thistles, and other composites, have tubes so deep that their nectar can only be removed by bees. As examples of deep narrow flowers, capable of being fertilised by moths and butterflies, may be mentioned—honeysuckle, Dianthus (pink), Lychnis, Phlox, and *Narcissus poeticus*. These are most select and exclusive as regards their guests, and it might be supposed that, from having fewer visitors, they would run a greater risk of not being fertilised than the shallower flowers do. To some extent this is true, but there is the compensating advantage that a single visit is far more likely to be efficient than in the case of open flowers, because the entrance to the flower is so narrow, that before the butterfly's proboscis can reach the nectar, it must inevitably touch the stigma and rub against the stamens. Hence less pollen will suffice. Accordingly we find that shallow flowers, like the rose and buttercup, have more numerous stamens and produce a much larger quantity of pollen than deep narrow flowers. Metaphorically, then, we may say that in flowers of the third type a few skilled hands are employed to do the same work which in shallow flowers of the buttercup type is performed by a much greater number of apprentices and unskilled labourers, while, as a consequence of this, there is a much greater waste of material in the shape of pollen in the latter, compared with the former. What is wanted is not merely that insects shall visit the flower, but that they shall also properly pollinate it, and it is a distinct advantage if the shape of the flower be such as to exclude all insects except those which are most capable of doing this work. Even in shallow flowers the necessity for excluding beetles and ants is felt, and the means adopted for the exclusion of these unbidden guests have been described by Kerner.

(*b*) Adaptations in the form of the corolla are still better seen in irregular flowers. In the dead-nettle, for instance, and many bilabiate flowers, the lower lip of the flower serves as a landing stage, on which a bee can readily alight in such a position that, on pressing into the flower, it is compelled to brush against the stigma and stamens. The upper lip serves as a roof to protect the pollen and nectar from rain, and also to retain the stigma and stamens in position. The size of the flower, too, so exactly corresponds to the size of the bee that it fits its body like a glove, so that the exact part of the insect's back, which in one flower has

touched the stamens and been dusted with pollen, will in another flower be certain to come in contact with the stigma. The same result is attained with greater or less precision in those irregular flowers which have a long deep pouch or spur containing the nectar—such as Indian cress (Tropœlum), the violet, valerian, larkspur, butterwort, toadflax, pelargonium, and orchid. The irregular flowers of aconite, calceolaria, antirrhinum, and the curious butterfly-shaped flowers of the bean order, all exhibit an equally remarkable adaptation. The extraordinary depth of the nectar-holders in many irregular flowers is astonishing—a Madagascar orchid being known with a nectary a foot long, where the nectar can only be accessible to some huge tropical moth, like that Brazilian one which has been described as having a proboscis ten or eleven inches long. The foregoing considerations will be sufficient to show that the form of the flower has an important relation to the visits of insects and to cross-fertilisation.

8. The position and arrangement of the organs within the flower exhibit a similar reference. In rhododendron and fuchsia the stigma protrudes from the flower, taking up its position directly in front of the nectar gland, so that a bee travelling in a straight line to enter the flower must inevitably glide over the viscid surface, leaving there the pollen it has brought with it from another flower. Once past the stigma the bee encounters the stamens, and can hardly miss carrying away some of their pollen when it leaves the flower. In the violet we have a most exquisite mechanical arrangement for preventing self-fertilisation and securing cross-fertilisation. At the entrance to the flower is the stigma, viscid on its outer aspect. It is somewhat cup-shaped, but the lower margin is prolonged into a movable lip or valve. A bee forcing its proboscis into the flower, bends this lip inwards, so that the proboscis is rubbed along the outer glutinous surface of the stigma, which appropriates any pollen that may be adhering to the proboscis, whereby the flower is crossed. The style upon which the stigma is borne has a knee-shaped bend, which gives the stigma a spring and enables it to regain its position. Immediately behind the stigma are the stamens of the violet. These cohere closely in a circle surrounding the style, and they might remain undisturbed were it not that from them proceed two little rods which are lodged in the hollow spur of the lower petal. On the further ends of these rods the honey is secreted, and during its removal they are moved by the insect. When thus moved they act as

levers, and dislocate the circle of anthers, so that a shower of pollen is discharged on the insect's proboscis. When the bee is about to retire from the flower, the valve of the stigma is elevated by the effort of the insect to withdraw its trunk, so that only the inner dry side of the lip comes in contact with the proboscis, and none of the violet's own pollen can by any possibility reach the viscid side of its stigma, which is now covered up by the folded lip. Any pollen on the proboscis will thus be removed from the flower, and, in all likelihood, deposited on the stigma of the next violet visited. Something resembling this arrangement exists in fumitory and Diclytra. In the flower of sage (*Salvia*) we meet with a curious adaptation. Each of its two stamens is provided with a hinge. When a bee enters the flower, its head does not come in contact directly with the pollen-bearing anther, but presses against a knob, causing the upper part of the stamen to revolve through ninety degrees, bringing down the pollen-bearing part so as to strike the bee on the back portion of its body. Here, then, it is not to the head nor proboscis that the pollen is applied, but to the exact part of the insect's body that will come in contact with the stigma when the bee happens to enter one of the older flowers of Salvia. The long and short styled dimorphic flowers of the primrose and bog-bean, and the trimorphism of Lythrum and Oxalis, are contrivances which secure the same end with still greater precision. Were further illustrations necessary to prove that the position and arrangement of the organs within the flower have the closest reference to the visits of insects, these might be indefinitely multiplied by having recourse to the two remarkable orders Orchidaceæ and Asclepiadaceæ.

9. The order in which the organs of a flower come to maturity has likewise a bearing on cross-fertilisation. The flower of *Aristolochia* (Birthwort) actually imprisons its insect visitors until its pollen is ready for them to take away. In the younger stage of this flower the stamens are not ripe, but the stigma is quite capable of being fertilised. Hence minute flies are allowed to enter. The tube of the flower is lined with stiff inward-pointing hairs. This mouse-trap arrangement admits of the insect's ingress, but prevents its exit. It is not till after the seeds have thus been fertilised with pollen brought to it in this way from another flower that Aristolochia produces pollen, and it does not allow the flies to escape until this happens. By this means it makes sure that they do not leave until they take its pollen with them to fertilise

another flower. The escape in the second stage of the flower is rendered possible by the mouse-trap hairs withering simultaneously with the maturation of the pollen. In the flowers of cuckoo-pint small flies are in a similar way subjected to temporary confinement for the same purpose. Both these flowers afford examples of protogynous dichogamy. Most ordinary flowers are protandrous—that is, their pollen is produced and removed before the stigma expands. According to the natural acropetal development of the floral organs, the stamens ought to be ready rather before the stigma, but this difference is often so strongly accentuated that the flowers become dichogamous, as in the wood geranium, mallow, and willow-herb. In many saxifrages the parts of the flower ripen alternately. In Parnassus, London pride, and rue, the newly-opened flower has five stamens, all immature, surrounding the pistil. One of these shortly afterwards elongates, bends over on the top of the seed-vessel, and there discharges its pollen, after which it curves outwards, receding towards the circumference of the flower. Its place is taken by a second stamen, which behaves exactly in the same way. The remaining stamens in turn likewise discharge their pollen in the same position, and finally, after the whole five have withered and all the pollen has been removed from the flower, the stigma expands its lobes in the position formerly occupied by the stamens, and arrives at a condition in which it is capable of fertilisation. In this case it is evident that the pollen for this purpose must be brought from a younger flower. The object secured by this remarkable development seems to be that the same part of the insect's body that came in contact with the stamen of a younger flower shall also touch the stigmas of the older flowers. Where such alternate dehiscence of anthers occurs, it will follow that at any given time five flowers will be producing pollen for every one which is in immediate need of it—a proportion which is highly favourable to cross-fertilisation by insects. Not only is the development of the organs composing the flower correlated to cross-fertilisation, but the succession of the flowers on the inflorescence is often of importance. We see this in the spikes of foxglove or Gladiolus. The lower flowers on the stalk, owing to the stamens in each flower being ripe before the stigma, are in the second or female stage, while the younger flowers higher up have only attained the earlier or male stage in which pollen is produced. The effect of this arrangement is that the bees, which, in

order to save time, always enter the lower flowers first, and proceed regularly upwards, deposit the pollen they have brought from another plant in the lower flowers, while before leaving the spike they are abundantly supplied with pollen from the younger flowers higher up. Were the bee to begin at the top and descend, it would lose time entering the newly-opened flowers which have no honey as yet, and would simply carry the pollen from the young upper flowers down to the lower ones on the same stalk—a mode of crossing, as we have seen, is little if any better than self-fertilisation.* These are but a few of innumerable examples of this correspondence between the mode of development of flowers and insects' visits that could be given.

10. The hour of the day when a flower unfolds its petals in some instances bears a manifest reference to the species of insect by which it is frequented. Dianthus, opening through the day, is fertilised by diurnal Lepidoptera, while the closely-allied *Lychnis vespertina* opens its flowers in the evening, and is visited by night-flying moths. The night-flowering stock (*Cereus grandiflorus*), which blooms at midnight and fades away before morning, is clearly suited to the visits of nocturnal insects.

11. The duration of flowers points to the same conclusion. Soon after fertilisation the petals droop and fade. This fact is but too familiar to gardeners, who are constantly annoyed by bees getting access to their greenhouses, and when once the stigma has been pollinated the flower seldom lasts any time. On the other hand, it is wonderful how long a flower will remain fresh and bright if it has not been visited. The fuchsia is a notable example of this. This plant, when growing out of doors, especially towards the end of the season, may often be seen with its flowers in perfect condition, after almost every coloured flower has disappeared, giving unmistakable evidence that it has been neglected by the bees. It is generally the case that an organ falls off when its function is performed, and so we might connect the petals with the work of fertilisation.

12. The power of movement, or irritability, sometimes resides in the organs of a flower. This endowment also favours cross-fertilisation. The stamens of berberry, rock-rose, Centaurea, and Kalmia move, when touched by an insect, in such a way as to

* *Vide* "On the Association of an Inconspicuous Corolla with Protogyny," by the writer.—*British Association Reports*, Dublin, 1878.

dust it over with pollen. In Mimulus (musk), the lips of the stigma close when touched—probably to retain the pollen. In Stylidium, the style is irritable, and when touched moves from one side of the flower to the other, the movement being connected with the removal of pollen from insects.

13. The carrion flowers, Stapelia and Rafflesia, afford the clearest evidence that the odours of flowers are of use in guiding insects to them. These flowers have the disagreeable smell of putrid meat, and appear to depend for fertilisation on the visits of foul-feeding flies. White and pale-coloured flowers have most scent. Nocturnal flowers have usually white or pale-coloured petals, and emit their perfume only at night. Thus, the delicious odour of *Lychnis vespertina* is hardly perceptible during the day, but most fragrant towards evening. During the few hours that the night-flowering stock remains in bloom it gives out puffs of odour at intervals—no doubt, with the object of attracting night-flying insects. Perfume ceases soon after fertilisation.

14. We come now to the markings on the petals, such as are seen on the violet, pelargonium, and Veronica. Regular flowers, like the rose and buttercup, which have all five petals of the same size and shape, have all five coloured alike; but in bilateral and irregular flowers the largest petal is generally differently coloured from the others. Some varieties of pansy have their petals so coloured as to remind one forcibly of a target, the entrance to the nectary corresponding to the bull's eye. This target type of colouration obtains on the petals of the eye-bright, forget-me-not, carnation, sweet-william, Polyanthus, Petunia, daisy, aster, Cineraria, and other composites. On the petals of such variegated flowers as the speedwell, pelargonium, Indian cress, rhododendron, ivy-leaved toad-flax, fox-glove, orchids, and bilabiate flowers—as the dead-nettle, ground ivy, and thyme—the lines and spots all converge and point in towards the nectar. This fact led Sprengel to the conclusion that these markings were intended as honey-guides to direct insects to the nectar. It is noticeable that night-blooming flowers never have such markings on their petals; but they would be of no service in the dark, and, doubtless, the odour makes up for this deficiency. In thus assisting the bees to discover the nectar quickly, it must not be supposed that this is done exclusively for the insect's behoof. It would be more correct to say that the use of the markings is to guide the insect so that it may enter the flower in the way most favourable to fertilisation.

In fact, while pointing to the nectar, these lines at the same time point to the stigma, and the nectary is always placed in such a position that in order to get to it the bee must pass the stigma, so that here the interests of the bee and flower coincide, for while the markings enable the insect to save time they render its visit more effectual. The importance of these "honey guides" is brought out strikingly by a consideration of the extraordinary industry of bees. The amount of sugar in flowers is often exceedingly minute—a pound of honey probably represents between two and three millions of flower visits.*

15. Colours. Wind-fertilised flowers, we have seen, are devoid of bright colours. When, then, we meet a brightly-coloured flower we may safely infer two things regarding it—1st, that it is not intended to be self-fertile; 2nd, that it depends on insects for cross-fertilisation. The first statement is abundantly proved from the case of cleistogamic flowers considered above; it remains to us only to adduce facts in support of the latter assertion. The importance of coloured petals has been shown by an experiment of Mr. Darwin's, which consisted in removing the petals from several flowers, and finding that they were not visited by the bees, which continued to frequent the surrounding flowers. Sir John Lubbock placed sugar on differently-coloured pieces of paper, and having accustomed a bee to a particular colour, found that when several colours were offered it, it almost invariably chose to take its sugar from the paper of the colour to which it had been accustomed. Still more recent experiments of the same kind tend to show that bees have a preference for certain colours, particularly for blue—and it is quite likely that the colours of flowers may be correlated to the tastes of particular insects, just as we have found their shapes determined with reference to the length and form of an insect's proboscis. The object of coloured petals, then, is to render a flower conspicuous—that it may easily be seen by insects. Conspicuousness may be attained by many small flowers clubbing together into a community, as in the daisy and clover, where each head consists of a multitude of little flowers, each of which, if growing by itself, would be quite invisible from a distance. Important organs of the flower are often sacrificed for the sake of greater conspicuousness. The white ray-florets of the daisy have a much larger corolla than the yellow florets in the centre; but

* *Vide* "Amounts of Sugar in Nectar of Flowers."—*Chemical News*, 1878.

this increased size of corolla is gained at the expense of the stamens, which are not present in the ray-florets. The larger flowers found towards outside of the inflorescence in Hydrangea and many umbellifers are neuter, their essential organs having been sacrificed to secure a larger corolla, and thus render the whole inflorescence more attractive. Now, when we call to mind the industrious, methodical, and business-like habits of the bees when engaged in collecting honey, it will be easily understood how it is to a flower's advantage to be conspicuous. A conspicuous flower will be less likely to be missed by bees hurrying to their task than an inconspicuous flower, and, from having more visitors, will stand a much better chance of cross-fertilisation. The bright hues of flowers serve the same purpose as the glaring colours of bills. In the one, the colour is intended to attract the attention of busy men as they pass and repass to their daily toil; in the other, the colour appeals to the eyes of the no less industrious bees as they hasten to and fro on their frequent and laborious errands.

We are now in a position to answer the question with which we started—for we have seen that the shape of a flower, the position and arrangement of its parts, the order in which its organs develop, the hour of day when it opens, its duration, its sensitivity, its odour, its markings, and its colour, are all determined in relation to cross-fertilisation. So far, then, from flowers being merely ornamental, all their parts have a share in, and the whole course of their development has a direct bearing on, the work of producing seeds—which is the true aim of all flowers—and herein lies the connection between flower and fruit.

EXPLANATION OF PLATES.

PLATE VIII.

Fig. 1.—Pollen-grain, showing the formation of the pollen-tube by the protrusion of the inner coat.

,, 2.—Pollen-grains on stigma (St), with pollen-tube passing down the style and coming into contact with the embryo sac within the single ovule.

,, 3.—Pollen-grain of campanula, showing the projections on its surface.

,, 4.—Unisexual flowers of hazel. F, pistil-bearing flower; M catkins of stamens.

Fig. 5.—Male catkin of willow produced on a separate plant from the female. (Diœcious.)
,, 6.—Single male flower of willow.
,, 7.—Female catkin of willow.
,, 8.—Single flower of willow.
,, 9.—Monœcious flowers of alder. F, female catkin; M, male catkin.
,, 10.—Flower of oat, deprived of glumes and paleæ, showing the slender stamens and feathery stigmas of the wind-fertilised class.
,, 11.—Wind-fertilised flower of rush.
,, 12.—Pistillate flower of carex.
,, 13.—Staminate flower of carex.
,, 14.—Staminate flower of chenopodium.
,, 15.—Pistillate flower of chenopodium.
,, 16.—Flower of scirpus, showing reduced perianth to favour wind-fertilisation.
,, 17.—Flower of rye-grass separated from spike.

Plate IX.

,, 18.—Shallow type of flower.
,, 19.—Type of bee-flower.
,, 20.—Deep flower, adapted to proboscis of butterflies and moths.
,, 21.—Section of violet. E, two cushions of hairs which shed off the rain; A, anthers; St, lip or valve of stigma, sticky on its outer side; N, rods secreting honey, lodged in P, the pouch or spur of the lower petal.
,, 22.—First stage of aristolochia. St, stigma ready to be fertilised; A, anthers not yet ripe.
,, 23.—Second stage of aristolochia. Mousetrap-hairs withered, stigma (St) fertilised; A, anthers discharging their pollen. This flower is protogynous.
,, 24.—Corolla of veronica with markings on the petals pointing to the nectar.
,, 25.—Flower of salvia. L, lower lip of bilabiate corolla; A, pollen-bearing anther-lobes; B, knob at end of connective against which the insect's head presses, causing A to revolve into position indicated by dotted lines; St, position of stigma in young flower altered by growth of style in older flowers to that indicated by dots. Flower protandrous.
,, 26.—Flower of malva, petals removed, showing first or staminate condition, the stigmas concealed and immature. (Protandrous.)
,, 27.—Second stage of malva. Stamens, having shed their pollen and withered the stigmas, begin to expand in the position formerly occupied by the anthers.
,, 28.—Pollen-masses of orchid.
,, 29.—Pollen-masses of asclepia.
,, 30.—Young newly-opened flower of parnassus. (Protandrous.)
,, 31 and 32.—Later, showing alternate dehiscence of anthers.

Fig. 33.—Last stage of parnassus, stigmas beginning to expand.

,, 34.—Section of flower of pelargonium. There is a deep narrow pit in the flower stalk which serves as a nectar holder, the nectar being only accessible to an insect with a long needle-like proboscis.

,, 35.—Section of fuchsia flower. G, honey gland; N, nectar-holder; St, stigma protruding.

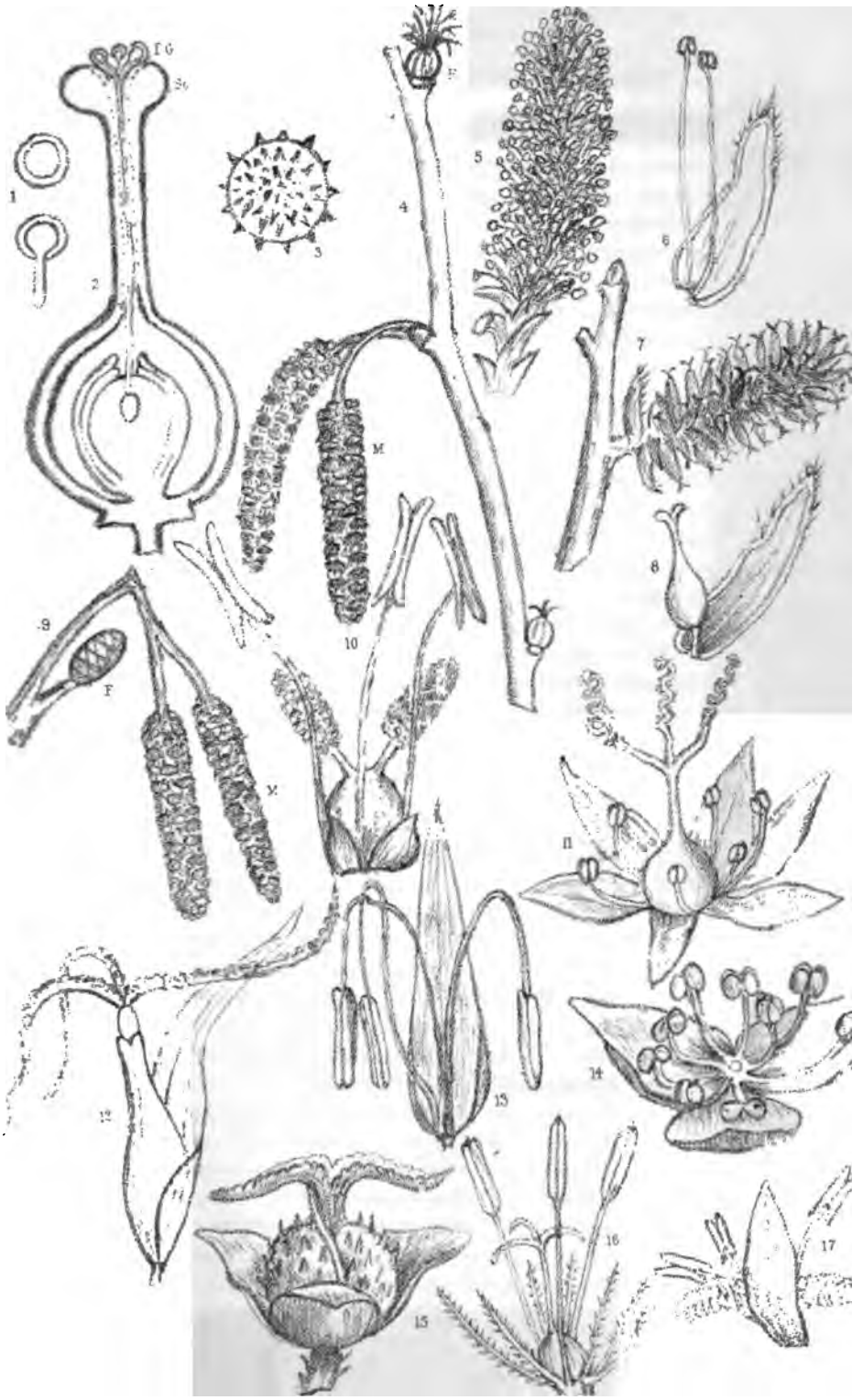
,, 36.—Flower of rhododendron. Stigma protruding so as to be encountered by an entering insect, stamens so placed as to be reached after the stigma has been pollinated.

,, 37.—Young flower from upper part of spike of gladiolus. Stamens standing in an insect's path to the nectar, stigma unexpanded and behind out of the insect's way.

,, 38.—Old lower flower of gladiolus, the stamens, having shed their pollen, rise to the upper side of the flower to be out of the way, while the style bends down and the stigmas unfold in the fair way to the nectar.

,, 39.—Petal of buttercup, showing the nectary on its surface, the pit or depression being inconsiderable.

,, 40.—Petal of closely-allied columbine, in which the depression is increased, so that the petal becomes a hollow spur with the nectar at its inner end. This deepening of the nectary excludes short-lipped insects and removes the flower from the first to the second or bee class.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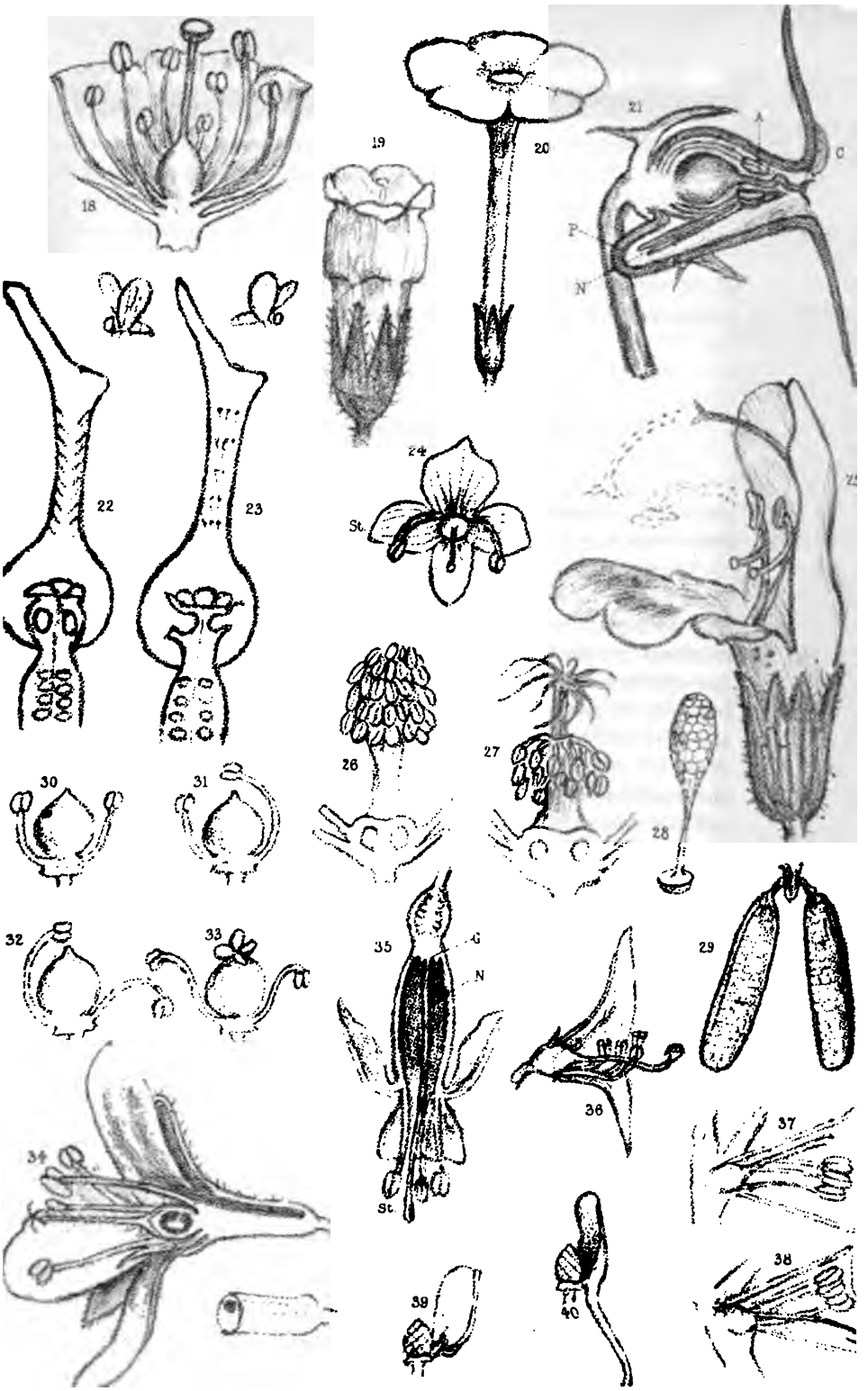
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XIX.—*On Algin—a new Substance obtained from some of the commoner Species of Marine Algæ.* By EDW. C. C. STANFORD, F.C.S., Vice-President.

[Read before the Chemical Section, 2nd April, 1883.]

THE utilization of hitherto waste materials presents a large field for chemical investigation, and many important industries have within the last twenty years resulted from such researches.

There are few materials so abundant, so general, and so easily obtained as the commoner kinds of sea-weed thrown up on all our coasts, but especially on those exposed to the waves and storms of the Atlantic. The species I refer to—the laminaria and fuci—are found growing on all rocky shores. And it may also be remarked that, except as manure, the great bulk of this material has been long practically unutilized. It is true that, when burnt into the rough slag known as kelp, this material was formerly the means of securing large revenues to the proprietors of the Western Islands. For several well-known reasons, that manufacture has long ceased to be profitable, and it never could have been considered as utilizing the sea-weed, except in the sense that burning down a forest could be called utilizing it, when it ought to be cut into timber and really utilized in building houses or making furniture.

In 1862 the writer introduced a method of carbonizing the sea-weed in retorts, and thus converting the material into charcoal instead of kelp, and preventing the great loss of iodine arising from open-air burning. This was simply another step of improvement, and comparing it again with the forest, was merely equal to making the timber into charcoal instead of burning it into ash. It is not, in a proper and fuller sense, utilizing the sea-weed. The results of further attempts in this direction form the subject of this paper. When we remark that the present wide-spread destitution and want of employment amongst the poor cottars is most severe in just those districts in Ireland and the Highlands where this material is most

abundant, the importance of this inquiry will be at once seen. Indeed, if a remunerative price can be paid for a waste material that every child in a large family can easily assist in collecting at their own doors, it would go far to settle many existing difficulties, of which the worst is always hunger. And this brings me to mention the value of the algæ as a food material. In my paper, read before the Society of Arts in 1862, on "The Economic Applications of Sea-weed," the various kinds so used were described, and I have called attention more recently, in a paper read before the Chemical Society, to the fact that the analysis of the charcoal obtained from the various algæ approximates more nearly to that of a product of the animal than of the vegetable kingdom. I believe the algæ generally to be quite as valuable food products as the fungi, with the advantage that we are unaware of any poisonous species. Both are, however, equally neglected in this country. As the edible fungi are much consumed by other European nations, so the edible algæ are largely enjoyed and realise a high price in China and Japan. A sample of one of the Japanese varieties before us yielded on analysis a composition closely similar to our laminaria. It has, however, evidently been cut up, and presents the appearance of long shreds, and is coloured green by the action of an alkali. The poor people in Donegal are now eating the Fucus vesiculosus with Indian meal, and it is a common thing to see the Highland cattle browsing on this plant at low tide. The Aliaria esculenta or murlins, of which a fine specimen is on the table, may be called our edible species, but the Rhodomenia palmata, or dulse, is perhaps better known in Glasgow, being regularly sold on the streets.

The most important species consumed in this country is the Chondrus crispus or Irish moss. This plant contains 79 per cent. of caragheenin, a substance of great gelatizing power, and largely used in jellies and puddings. This sea-weed would, no doubt, secure a considerable market as a size for fabrics, but it cannot be obtained in any great quantity. It is only uncovered at low spring-tides, and any very large demand would soon exhaust the supplies. A recent application of Irish moss is being worked by a limited company under the name of Velo-plastic, which is said to be made of refuse leather, dried and finely ground and mixed with caragheenin. I am indebted to Mr. John A. Walker, of Dublin, for specimens of green and yellow morocco, poplin, and satin damask, and watered silk, all of which appear to be most successful

imitations. The new substance to be described in this paper would probably answer equally well for this application.

Another still more powerful gelatizing substance is gelose. This was first imported into France from China in 1856. It has ten times the gelatizing power of isinglass, and will set into a jelly 500 times its weight of water. It is not nitrogenous, and contains—carbon, 42·8; hydrogen, 5·8; oxygen, 51·4. It has not superseded isinglass for jellies, as the fusing point of the jelly is too high to melt in the mouth. I found some years ago, in experiments on every variety of sea-weed that could be procured, that this gelatizing principle was confined to two British species—the Chondrus crispus and the Gelideum corneum. An Australian alga, the Euchemia spinosa, or agar agar, is also a jelly-yielding species. Several articles have recently been introduced under various names, such as thao, fucyne, &c., all of which appear to be modifications of, or products from, these plants.

The application of sea-weed as manure is very general where it can be obtained. In fact, the practical value placed on it is far above its actual chemical valuation. It usually contains 80 per cent. of water, so that four tons of water are carted to the land for every ton of dry sea-weed, and even when dried there is not a large saving in carriage, as it is then very bulky. It is, however, carried long distances in some places, and there is no doubt that it is very valuable on soils that are all sand; but it is more of a mechanical value, as its use is not to *manure* but to *make* the soil—a rather expensive manufacture. Kelp waste—a ton of which, dry, represents 40 tons of wet sea-weed, and contains all the phosphates of the weed in a convenient form—is absolutely unsaleable to farmers in this country at any price.

The only other important proposed application of sea-weed has been to the manufacture of paper, and about 20 years ago several patents were taken out with this object, and some specimens were exhibited at the Society of Arts on the occasion before referred to. They were all made, however, from the Zostera marina, or grass wrack—a marine plant with flowers growing in the sea, but not one of the algæ—and this plant makes a very good paper. It created a good deal of attention at that time, having been proposed as a substitute for cotton during the cotton famine. It is not, however, available in large quantity, and contains very little fibre. The algæ generally contain no fibre, but, as far as my experiments have gone, nearly every species yields a very pure cellulose, which makes a

tough, rather transparent paper. The tissue of the plant consists of simple cells of various shapes laid end to end, and in the fuci containing a dark pigment. This cellulose fabric, which forms the paper material, amounts, when quite dry, to 10 per cent. of the air-dry plant. In working on the fuci and the laminariæ my attempts to make a paper pulp were much impeded by a peculiar substance common to both these species, which was found at first difficult to remove, and the presence of which rendered the paper brittle. In fact, this appeared to be always the case unless the cellulose was obtained quite pure. This substance is present in large quantity, and forms the bulk of the plant after the salts are removed.

Any one observing the long flat fronds of the laminaria lying on the sea shore must have noticed two things—1st, that these are easily bleached by exposure to light; 2nd, that, after exposure to rain, the fronds contain in their interior sacs of fluid. These are derived from the endosmosis of the water through the outside membranes, dissolving a peculiar glutinous principle. Upon opening one of these sacs, a neutral glairy, almost colourless, liquid escapes. Sometimes it may be seen partially evaporated on the surface of the frond as a jelly-like substance, which may be drawn out by the fingers in long, tenacious strings. This fluid contains a unique substance of remarkable properties, and to which, from its source, I have given the name of algin. The vesicles are only seen in the long fronds of the various laminaria, especially L. stenophylla, known in the Highlands as bar-darrig, or red-top. The large stems or tangle, and the fuci, although containing it in considerable quantity, do not exhibit this appearance.

If the liquid be evaporated to dryness, the scales so produced resemble albumen, and are not all soluble in water, but very soluble on the addition of a little alkali. Several other instances of the solubility of substances when endosmosed or dialysed are well known. The fluid thus naturally obtained is miscible with water, but coagulated by alcohol and by mineral acids. It cannot be obtained in sufficient quantity for exhaustive analysis, but it contains calcium, magnesium, and sodium, in small quantity, in combination with algin. If the laminaria fronds are cut up and macerated in dilute hydrochloric acid, the liquid in the vesicles assumes the form of a colourless, insoluble jelly. If the laminaria fronds are immersed in water containing a little alkali—by preference sodium carbonate—the whole plant becomes disintegrated, and presents a gelatinous mass, consisting of a thick, glutinous, gummy liquid,

containing the cellular fabric of the plant completely broken up. This occurs in 24 hours in the cold. The mass, although it only contains 2 per cent. of the algin, is so glutinous that it cannot be poured out of the bottle. It is very difficult to deal with, on account of its extraordinary thickness. In fact, as it is, no method of filtration is possible (all known methods, with and without pressure, have been tried). The cells to be removed are so minute that, if pressure be applied, the whole mass passes through any filter or not at all. By cautiously heating the mass, it can, however, be filtered. The medium employed is a coarse linen sacking in the form of a Taylor's filter. The cellulose is left behind as a gelatinous mass, amounting, when dry, to about 10 per cent. of the air-dried plant.

The algin solution is then evaporated in a somewhat similar manner to gelatin, and, when dry, presents an appearance which is not unlike gum-tragacanth; but it may also be obtained in thin transparent flexible sheets. The solution is slightly alkaline; but care must be taken that no great excess of sodium carbonate is present, or the solution decomposes, and in a week, if dilute, becomes quite thin, and contains no algin. This action of the alkali I cannot yet clearly explain. The solution can be neutralised by the careful addition of hydrochloric acid without gelatinizing; but an excess at once precipitates it. A solution of only 2 per cent. becomes semi-solid, treated in this way. The following reactions are obtained with various reagents. For some of these the solution must be carefully neutralised with acetic acid, which does not gelatinize it.

Dilute hydrochloric, nitric, sulphuric, sulphurous, phosphoric, and mineral acids generally, coagulate it. Boracic acid has no effect.

Lime water, baryta water, and salts of calcium, barium, and strontium, give white precipitates.

Salts of magnesium do not affect it. Acetic, formic, citric, tartaric, and benzoic acids do not affect it.

It is precipitated by alcohol.

Perchloride of iron gives a dark brown coagulum.

Salts of copper, zinc, aluminium, tin, antimony, cobalt, and nickel, all precipitate it.

Protonitrate of mercury forms a white precipitate, but bichloride of mercury and silver nitrate have no effect.

Acetate and subacetate of lead both give white precipitates.

Potassium silicate and bichromate, sodium biborate* and potassium ferro-cyanide, permanganate, sodium tungstate, stannate, and succinate do not affect it. No precipitate is produced by tannin.

Concentrated sulphuric acid dissolves it; concentrated nitric acid converts it into oxidation products, amongst which are oxalic acid, of which a specimen from this source is exhibited.

It is distinguished from albumen by not coagulating on heating, and by not precipitating silver nitrate—from gelose by not gelatinizing on cooling, and by containing nitrogen, which gelose does not; and being soluble in cold, weak, alkaline solutions, which gelose is not; and being insoluble in boiling water, in which gelose is soluble. The laminaria has been boiled in water for a month without effecting any solution, and for a week under 40 lbs. pressure with a similar result.

It is distinguished from gelatine by not giving any reaction with tannin—from starch by giving no reaction with iodine; from dextrine, gum-arabic, gum tragacanth and pectin, by its insolubility in dilute alcohol and in dilute mineral acids.

I notice as particularly remarkable that it should precipitate all the salts of the alkaline earths except those of magnesium, and most of the metals except silver and mercury, and with regard to the latter that it should precipitate the protonitrate but not the bichloride; and that it gives no precipitate with potassium silicate.

The gelatinous precipitate produced by a mineral acid represents the algin in its pure insoluble form. It dries up to a hard, horny substance. The specimen shown can scarcely be distinguished from horn. I have not yet succeeded in getting it pure and definite enough to be certain of its composition; but I am indebted to Professor Ferguson for a combustion of the soda compound. This had been carefully dialysed to avoid the presence of excess of alkali, and gave the following numbers:—

Carbon, ...	35·65
Hydrogen, ...	4·40
Nitrogen, ...	3·03
Oxygen, ...	37·23
Ash, ...	19·69
	100·00

* It can be extracted by a solution of borax.

This gives the following composition for the algin. I have appended also that of gelatin, isinglass, gelose, and chitin. In nitrogen it is intermediate between gelose and gelatin, but it approaches nearer to chitin than any other substance. Fremy, however, denies the presence of nitrogen in this substance. It differs entirely from algin in being insoluble in alkalies.

	Algin.	Gelatin.	Isinglass.	Gelose.	Chitin.
Carbon, ...	44·39	50·0	50·1	42·77	46·64
Hydrogen, ...	5·47	6·5	6·6	5·77	6·60
Nitrogen, ...	3·77	17·5	18·3	...	6·56
Oxygen, ...	46·37	26·0	25·0	51·46	40·20
	100·00	100·0	100·0	100·00	100·00

(Sulphur, ·12.)

The percentage of ash in the soda compound does not materially vary. The two following were made—one with sodium hydrate, and the other with sodium carbonate—and yielded almost the same amount of ash :—

Sodium hydrate—percentage of ash, ...	31·51
Sodium carbonate do., ...	31·37
Mean, ...	31·44

Although I believe the composition to be stated correctly, I cannot construct a formula from these figures; and all attempts to procure definite compounds for analysis have as yet been unsuccessful. The following salts have been prepared and investigated with thi view :—Compounds with calcium, aluminium, barium, and lead—but the results have not been uniform enough to show that we have been examining definite compounds.

The sodium carbonate appears to be unaltered in the compound, but completely masked. The carbonic acid comes off only when acidified with an excess of hydrochloric acid, and heated.

The acid has also some decomposing effect, and produces a small quantity of a substance which precipitates Fehling's solution, but does not appear to be glucose.

A solution, 1000 grs. measure, containing 13·2 grs. of algin,

was precipitated by standard sulphuric acid, and redissolved by standard sodium hydrate, six times in succession.

1st precipitation took of sulphuric acid (SO_3), grains,			...	5·430
2nd	"	"	...	4·070
3rd	"	"	...	3·086
4th	"	"	...	1·975
5th	"	"	...	0·617
6th	"	"	...	0·617

1st resolution took of soda (Na_2O), grains,			...	3·778
2nd	"	"	...	2·871
3rd	"	"	...	2·052
4th	"	"	...	1·530
5th	"	"	...	0·670
6th	"	"	...	0·478

As the precipitate is not soluble in sodium sulphate, there appears to be some decomposition continually going on, and this has not yet been sufficiently investigated to enable me to ascertain the exact action of the hydrochloric acid.

The process proposed to deal with the sea-weed is first of all to wash out the salts by simple maceration in cold water. This is very easily done, the salts being almost entirely removed, even by two macerations. On account of the bulk of the material it is, however, advisable to wash a number of vats exhaustively in turns, in the usual manner of lixiviation common in alkali works. The water removes about a third of the weight of the sea-weed, and when evaporated to dryness presents a treacly mass containing the salts and a considerable quantity of a saccharine matter which resembles mannite, but which precipitates Fehling's solution equal to 15 per cent. of glucose. It is, however, unfermentable, and I have not yet succeeded in getting it pure enough for analysis, on account of the great difficulty of separating it from the alkaline chlorides which are soluble in alcohol. By the use of sulphate of silver I have separated a small quantity, but still not sufficiently pure. If this can be separated commercially, and is a sugar having sweetness but unfermentable, it would be available for replacing glycerine in some of its applications. Until, however, more is known of its properties it must be sacrificed by carbonizing the salts, the charcoal, of which it yields about 50 per cent., being then treated in the usual manner for separating the iodine and salts. The salts vary from 35 to 55 per cent. of the whole; or 12 to 18 per cent. of the original air-dry weed in the laminaria. This is

more than is obtained by burning the weed into ash, which does not, as a rule, yield more than 10 per cent. of salts on the air-dried weed.

It is interesting to notice the way in which these salts come out, and analyses have been made with this view. The results are shown in the following tables:—Calcium sulphate and magnesium chloride are both present in the aqueous solution of the laminaria and in the residue of the fuci—carbonates generally in the salts of the fuci and the residue of the laminaria. In the latter, which is always submerged, the relation of the magnesium to the calcium is singularly like that existing in sea water.

Within certain limits the composition of the salts differ considerably, the age of the plant and the time of gathering both affecting it.

The following samples are from a considerable bulk of mixed salts evaporated:—

ANALYSES OF THE SALTS.

	Laminaria Stenophylla.	Fucus Vesiculosus.
Calcium sulphate, ...	1·69	4·33
Potassium sulphate, ...	11·29	23·62
Potassium chloride, ...	19·90	13·71
Sodium chloride, ...	60·96	58·20
Magnesium chloride, ...	4·35	—
Sodium carbonate, ...	·53	—
Sodium iodide, ...	1·26	·12
	99·98	99·98

In the following tables the composition of the salts are shown as they come out in six successive macerations in cold water.

The residues are always carbonized, and then washed and again ignited—that being the only way to insure perfect combustion in the presence of such an excess of saline constituents.

Laminaria Stenophylla—Air-dried, Containing 14·8 Moisture.

4 oz. = 1750 grains. Six macerations in cold water—all evaporated, and residues weighed.

	Grs.	Per cent.	Grs.	Per cent.
1st water-weight of residue, ...	288	16·45	499	= 28·5
2nd " " ...	211	12·05		
3rd " " ...	40	2·28	77·2	= 4·4
4th " " ...	37·2	2·12		
5th " " ...	21·1	1·20	39·7	= 2·26
6th " " ...	18·6	1·06		
	615·9	= 35·16 per cent.		

	1	2	3	4	5	6
Volatile matter, ...	23·4	28·0	29·3	40·0	54·5	69·1
Salts, ...	67·1	60·1	55·5	40·0	31·8	22·5
Fixed carbon, ...	3·91	4·97	4·1	4·56	2·23	·96
Ash, ...	5·59	6·93	11·1	15·44	11·4	7·44
	100·0	100·0	100·0	100·0	100·0	100·0

Composition of Salts.	1	2	3	4	5	6
Calcium sulphate, ...	2·91	1·02	Nil.	Nil.	Nil.	Nil.
Potassium sulphate, ...	7·53	10·08	19·48	20·80	Trace.	Trace.
Potassium chloride, ...	34·05	30·95	24·81	23·78	"	"
Sodium chloride, ...	45·55	53·00	53·57	51·04	"	"
Sodium iodide, ...	1·95	1·58	2·00	1·25	"	"
Sodium carbonate, ...	Nil.	Nil.	Trace.	3·30	"	"
Magnesium chloride, ...	8·55	3·40	Trace.	Trace.	"	"
	100·54	100·03	99·86	100·17	"	"

LAMINARIA STENOPHYLLA—AIR-DRIED.

Calculated percentage on Original Weed.

	Per cent.	Volatile.	Salts.	Carbon.	Ash.
1st Water, ...	16·45	3·85	11·04	0·64	0·92
2nd "	12·05	3·35	7·26	0·60	0·84
3rd "	2·28	0·68	1·26	0·09	0·25
4th "	2·12	0·86	·85	0·09	0·32
5th "	1·20	0·656	·38	0·027	0·137
6th "	1·06	0·732	·24	0·010	0·078
	35·16	10·128	21·03	1·457	2·545

COMPOSITION OF SALTS.

	1	2	3	4	5	6	Total.
Calcium sulphate, ...	0·321	0·074	Nil.	Nil.	Nil.	Nil.	0·395
Potassium sulphate, ...	0·831	0·731	0·245	0·177	Trace.	Trace.	1·984
Potassium chloride, ...	3·759	2·247	0·312	0·202	"	"	6·520
Sodium chloride, ...	4·970	3·846	0·678	0·432	"	"	9·926
Sodium iodide, ...	0·215	0·115	0·025	0·011	"	"	0·366
Sodium carbonate, ...	Nil.	Nil.	Trace.	0·028	"	"	0·028
Magnesium chloride,...	0·944	0·247	Trace.	Trace.	"	"	1·191
	11·040	7·260	1·260	0·850	0·38	0·24	21·030

LAMINARIA STENOPHYLLA—AIR-DRIED.

Residual weed—Weight 2 oz., or 50 per cent.

		Calculated on original weed per cent.
Volatile matter, ...	74·2	37·1
Charcoal, ...	25·8	12·9
	100·0	50·0
CHARCOAL.		
Salts, ...	18·0	2·32
Fixed carbon, ...	50·7	6·55
Ash, ...	31·3	4·03
	100·0	12·90
SALTS.		
Potassium sulphate, ...	35·27	·818
Potassium chloride, ...	6·72	·156
Potassium carbonate, ...	5·00	·116
Sodium carbonate, ...	49·97	1·169
Sodium iodide, ...	2·63	·061
Alkaline earths, ...	Nil.	Nil.
	99·49	2·320

FUCUS VESICULOSUS—DRIED.

Containing 2·11 per cent. Moisture.

4 oz. = 1750 grs. Six macerations in cold water—all evaporated, and residues weighed.

	Grs.		Per cent.	
1st water-weight of residue,	174·5	=	9·45	11·90
2nd " "	43·0	=	2·45	
3rd " "	11·2	0.64	= 0.99	
4th " "	6·15	0·35		
5th " "	Trace.			
6th " "	Trace.			
	234·85	=	12·89	

	1	2	3	4
Volatile matter, &c., ...	37·78	68·4	47·48	62·86
Salts, ...	49·03	27·62	29·22	25·71
Fixed carbon, ...	8·09	1·17	3·78	·74
Ash, ...	5·10	2·81	19·52	10·69
	100·00	100·00	100·00	100·00

SALTS.

	1	2	3	4
Potassium sulphate, ...	27·25	48·19	Trace.	Trace.
Sodium sulphate, ...	4·03	·57	"	"
Sodium chloride, ...	61·50	37·62	"	"
Sodium iodide, ...	·026	·02	"	"
Sodium carbonate, ...	7·42	13·36	"	"
	100·226	99·76	"	"

* FUCUS VESICULOSUS—DRIED.

Calculated on original Weed.

	Per Cent.	Volatile.	Salts.	Carbon.	Ash.
1st Water, ...	9·45	3·58	4·63	0·76	0·48
2nd ,, ...	2·45	1·68	0·67	0·03	0·07
3rd ,, ...	0·64	0·304	0·187	0·024	0·125
4th ,, ...	0·35	0·221	0·089	0·003	0·037
5th, Trace, ...	—	—	—	—	—
6th, Trace, ...	—	—	—	—	—
	12·890	5·785	5·576	0·817	0·712

* This specimen was abnormally low in Salts.

COMPOSITION OF SALTS.

	1	2	3	4	Total.
Potassium sulphate, ...	1·262	0·343	Trace	Trace	1·605
Sodium sulphate, ...	0·186	0·004	,,	,,	·190
Sodium chloride, ...	2·8378	0·2337	,,	,,	3·0715
Sodium iodide, ...	0·0012	0·00013	,,	,,	·00133
Sodium carbonate, ...	0·343	0·0895	,,	,,	·4325
	4·630	0·6700	0·187	0·089	5·576

RESIDUAL WEED—FUCUS VESICULOSUS.

Weight, 3 oz. 175 grains = 85 per cent.

		Calculated on original weed.
Volatile matter, ...	65·65	55·81
Charcoal, ...	34·35	29·19
	100·00	85·00
CHARCOAL.		
Salts, ...	18·63	5·24
Fixed carbon, ...	58·53	17·53
Ash, ...	22·84	6·42
	100·00	29·19
SALTS.		
Potassium sulphate, ...	29·41	1·5420
Sodium sulphate, ...	47·58	2·5030
Calcium sulphate, ...	9·34	0·4760
Magnesium sulphate, ...	11·76	0·6160
Magnesium chloride, ...	1·30	0·0680
Sodium carbonate, ...	·45	0·0235
Sodium iodide, ...	·22	0·0115
	100·06	5·2400

After the salts have been removed, the weed is bleached by a weak solution of chlorinated lime, about 2° Twad. The laminaria bleaches easily in a few hours, but the fuci require prolonged and repeated treatment. I would call attention to the extreme beauty of some of the algæ before you when thus bleached; even in the common fucus vesiculosus, or black wrack, you can trace the spores in the cells and the lining of the air-vessels. The specimen

of Sargassum bacciferum (gulf weed) is beautifully transparent. Other specimens shown are Laminaria digitata, stems and fronds, the former looking like sticks of ivory, L. stenophylla, Fucus nodosus, F. serratus, Aliaria esculenta, Halidrys siliquosa, Rhodomenia palmata, Rhodomela pinnastroides, Zostera marina, Enteromorpha compressa, &c. When sufficiently white, the weed is soured by a very weak solution of sulphuric or hydrochloric acid, and well washed. If the acid be added with the bleach the action is quicker. It is then acted on in the cold by about a tenth of its weight of sodium carbonate for 24 hours, then heated, filtered, and evaporated. The residual cellulose is pressed into cakes for use as a paper material. It is already bleached, and has only to be put at once into the paper beater. There are plenty of fibrous materials in the market, but there is no real substitute for rags, as, I believe, this will to a great extent prove to be.

The whole of the plant is thus accounted for; in the laminaria, the average yield is as follows:—

On the air-dried plant—

Extracted by water, ...	30
Extracted by acid, ...	5
Extracted by Sodium Carbonate = Algin, ...	35
Cellulose, ...	10
Moisture, ...	20
	100

This plant is the only one now employed in making kelp; the least exposure to rain washes out the salts, and renders it useless for this purpose. It does not, however, interfere with its use for extracting the Algin, which is insoluble in water. For this purpose, if the salts are sacrificed, it is improved by exposure to rain and light. The wet weed, however, keeps perfectly well if access of air be prevented, for instance in a properly constructed "Silo," and there is no reason that any of it should be lost.

APPLICATIONS OF ALGIN.

Algin has properties which should make it useful for several applications in the soluble form. As a stiffener of fabrics, although not so rigid as starch, it fills the cloth better, is tougher, more elastic, and more transparent. It mixes in all proportions

with starch and dextrine, and imparts to the mixture these properties. Unbleached, it forms a cheap material for dressing winseys and such dark goods. Passed through an acid bath, the coating becomes glossy and insoluble, and thus a vegetable mordant is available for dyeing. Lime-water, and salts of calcium, barium, and several metallic salts, may be employed for a similar purpose; one of its peculiarities being the ease with which it is rendered insoluble.

I shall only just refer to its probable value as a food material on account of its nitrogenous character, as I have no edible specimens on the table which can be passed round for immediate consumption. As a cattle food there is a large opening for such a material. The agglutinating power of algin enables us to convert into solid blocks many substances which are with difficulty made to cohere. Silica, lime, magnesia, oxide of zinc, phosphate of lime, alumina, chalk, plumbago, charcoal, and many other such substances can be converted into solid hard blocks. All of these and many more are exhibited. Some of these compounds may be made by mixing the algin with a solution, where both form a joint precipitate with another solution—*e.g.*, sodium silicate, and calcium chloride. One application of this agglutinating character has already assumed importance. Charcoal has been long known as our best solid non-conductor of heat, and no doubt it would have been employed long ago as a covering for our steam-boilers, had any medium been known capable of agglutinating it. That is now attained by this substance. My "carbon cement,"* for this purpose, contains 97 per cent. of charcoal, 3 per cent. of algin being sufficient to make it cohere; and as that charcoal is made from sea-weed, it is a remarkable fact that the whole covering is derived from that material. My friend, Mr. Spiller, a high authority on the subject, has also found the solution of algin the best thing yet discovered for arresting incrustation in steam-boilers. We are not much troubled with this in Glasgow, but in the south, where the waters are hard, many such fluids are employed. Most of these are organic compounds combined with alkalies. One of the earliest and best was introduced some years ago by Mr. Spiller himself, and I am entirely indebted to him for

* Carbon cement forms a very light, inodorous, and cheap material for covering steam-boilers. Over 20,000 square feet have already been applied to boilers and piping.

suggesting the application of algin to this purpose. He speaks of it as highly efficient in precipitating the lime in such a fine state of division that it can easily be blown off from the cock. So that we now propose seaweed in one form or other as a most comfortable internal and external application to our steam-boilers. In fact, several large steamers are already ploughing the ocean assisted in their daily conflicts with heavy seas by weapons borrowed from these opponents.

The insoluble form of algin is very like horn, and as it can be pressed into moulds of any size it may be used instead of that article.

It also appears to be an excellent non-conductor of electricity, and in combination with certain other substances may assist in providing the cheap non-conductiug material, which shall be impervious to moisture, now so much required for underground telegraph and telephone wires.

It is an efficient agent for emulsifying oils, and, being coagulated by alcohol, for fining wines and spirits.

These are some of the probable applications of algin, and, seeing that the substance is new, and the source abundant, I shall not be bold enough to predict what it may *not* be used for.

XX.—*Address to the Chemical Section.* By ROBERT R. TATLOCK, F.R.S.E., F.I.C., F.C.S., President.

[Read before the Section, 5th February, 1883.]

IT might be expected that I, who have been connected with this Section of the Philosophical Society of Glasgow during one-third of my entire lifetime, should be able to say a good deal with regard to its history, the work it has done, and the purpose it has served; and, truly, this would not be a difficult task to any one, who, like myself, is familiar with the many valuable and important papers which its members and associates have read, and the discussions contingent upon them in which they have taken part. But there are considerations which tempt me in a different direction, and I shall therefore, on this occasion at least, not indulge in a review of its proceedings, although such could not be anything else than a long and pleasant eulogy, but shall only take a passing glance at its origin, progress, present condition, and future prospects.

The Chemical Section of the Philosophical Society of Glasgow was instituted in the year 1868, and to the exertions of Mr. E. C. C. Stanford, who has since filled the office of President during the term of three years, we are mainly indebted for its establishment then. With a total membership, at the start, of 65, and the late worthy Professor of Chemistry in the University—Dr. Thomas Anderson—as its President, its prospects were good and fair; and the retrospect of 15 years shows that these have been fully and completely realised. Many of the communications have taken rank with the best that have been published during the existence of the Section, and were the outcome of the most patient and laborious investigation. And not only in this respect has it been of service; it has opened the reading-room of the Society to its associates, and even if it had done no other work than that of establishing the Graham Memorial Fund, it would not have existed in vain. The object of this was to perpetuate the memory of that distinguished chemist and gentleman, by the delivery, at regular

intervals, of a lecture to the Section by some one of the most distinguished chemists of the day, and by the bestowal of a gold medal, at regular intervals, for the best paper read to the Section on any chemical subject—scientific or technical. I feel it to be impossible to refer to this matter without associating with it the name of Mr. Thomas R. Ogilvie, of Greenock, who originally proposed the scheme, and of Mr. Alexander Whitelaw, who supported the proposal by offering the first medal.

It has recently been suggested, but not by any means formally proposed, that the Section should, in a certain measure, be merged into the parent Society—at least as far as the reading of papers is concerned. Many of these are not of so technical or special a character as to be uninteresting to the bulk of members, and even if they were, by a judicious combination of papers read on the same evening, the interest, and consequently the attendance, of members would be maintained. Under this arrangement the Section would retain its name and its office-bearers, and all its functions would be unimpaired. I do not venture to pass any opinion at present as to the desirability of carrying out this proposal; there are many points to be considered which could only be fully gone into, with the aid of the Secretaries of the Society and of the Sections.

The necessity for the continuation of a chemical society of some kind in Glasgow is proved, not only by the existence of this Section for so long a period, but by reason of the great diversity of chemical manufactures in this city and its neighbourhood. I know of no centre where such variety in that respect is to be found—indeed, there is scarcely a branch that is not largely represented. There are districts in the country, such as those of St. Helens and Newcastle, where a particular chemical manufacture is carried out on a more extensive scale, but, in point of variety, I know of none that can approach this one. The manufacture of sulphuric, hydrochloric, nitric, and acetic acids; soda ash, and crystals, bleaching powder; muriate, sulphate, carbonate, bichromate, chlorate, and the red and yellow prussiates of potash; iodine, borax, saltpetre, gunpowder, nitro-glycerine compounds, ammonia salts, paraffin oil, and wax; phosphorus, artificial manures, iron and steel; copper, zinc, pigments, are largely represented, and sugar refining, bleaching, Turkey red, and general dyeing, and calico printing, are extensively carried on in Glasgow and the West of Scotland; indeed, the wonder is that these extensive industries can be conducted with so little chemical intercourse, not to speak of instruction and training.

There is, perhaps, no series of industries liable to such sudden changes—such complete metamorphoses—such almost capricious alterations—as those of a chemical character. So much is this the case, that it is now becoming very hazardous, even for persons highly skilled in scientific and technical matters, to embark in them. Many branches of chemical manufacture have assumed a totally different aspect of late, others have been practically extinguished, and it is to a few of these remarkable changes, that have taken place since the establishment of this Section, that I would seek to direct your attention, briefly, this evening.

I begin with the manufacture of products from kelp—one of the industries which, we might almost say, was peculiar to Glasgow. Its history is a remarkable one. At the beginning of the present century, kelp, or the residue which is left on the incineration of sea-weed, was made on the shores of Scotland alone to the extent of 20,000 tons per annum, and had then a value of at least £20 per ton, the value of the entire production therefore being about £400,000. It was used to some extent in glass-making, but was wrought principally for the carbonate of soda, or "alkali," which it contained in the proportion of from 10 to 15 per cent., and which was extensively employed in the manufacture of soap. A corresponding product—barilla—was made, by the burning of sea-weed, on the southern shores of France and Spain, and being somewhat richer in alkali, competed successfully with kelp in this country for upwards of 20 years, notwithstanding the duty upon it—which was equal to half its selling price, causing an average reduction in price to the extent of 50 per cent., during that period. From various causes, but particularly on account of the removal of the duty on barilla, kelp gradually fell to from £2 to £3 per ton, at which rate its production was no longer remunerative. This state of things continued till the year 1845, when the demand for iodine, and its sudden increase in value from 7s. to about 40s. per lb., resulted in its manufacture from kelp, and the value of the latter was no longer determined by the proportion of alkali, but by the amount of iodine it contained. Even then, muriate and sulphate of potash were being made from kelp, but were consumed chiefly in the manufacture of alum. Two or three years later, the introduction of the process for making British saltpetre, by the double decomposition of muriate of potash with nitrate of soda, enhanced the value of the potash salts, and this was further aided by the application of the Le Blanc process to the production of carbonate of

potash, or British pearl-ash, from the muriate of potash; and these innovations respectively, on the other hand, greatly diminished the otherwise value of Bengal saltpetre, and of American potashes and pearl-ashes.

Glassford, in an admirable paper, communicated in 1848 to the Glasgow Philosophical Society, tells us that in 1845 there were only four works in the Glasgow district engaged in the manufacture of kelp products; but these rapidly increased to 20, working collectively say 4,000 tons of kelp per annum. The price of iodine was then £1 1s. per lb., and that of muriate of potash considerably over £20 per ton. For the next dozen years or so, the average amount of kelp wrought in this district was about 7,000 tons (though it finally rose to 14,000 tons), the average price of iodine about 12s. per lb., and the cost of muriate of potash from £10 to £14, rising in 1861 to £20, and in 1862 to £22 per ton. Then came the first symptom of the changes which were in store for this industry.

The Prussian Government, which had been putting down a shaft in the neighourhood of Magdeburg to work rock salt, came upon a bed of the celebrated "carnallit" or double chloride of potassium and magnesium, and in the year 1857 raised their first quantity of 692 tons. Much delay, however, occurred before the muriate of potash was obtained from it in sufficient quantity to affect the potash market, and it was not till 1862, when 20,000 tons were raised, that matters began to look serious, as this quantity represented more than 3,000 tons of average commercial muriate of potash. In the same year the Government of the Duchy of Anhalt, encouraged by the Prussian successes, sunk a shaft on their own territory, and struck the same carnallit bed, raising that year only 215 tons, but in the following year 17,000 tons of the mineral. The price of muriate of potash now rapidly fell until it reached half its former rate, at which, with certain fluctuations, it has remained. Some idea of the gigantic character of this industry may be gained from the fact that, in 1875, 33 chemical works in the immediate vicinity of the two shafts worked up 500,000 tons of carnallit into muriate of potash, the products having a total value of over £700,000.

These quantities are quite independent of what are capable of being produced by the Douglashall Mines, about 20 miles distant, where the pure carnallit is at least 400 feet thick, and where I have seen at least 6,000,000 tons in sight. It seems no wonder

that the manufacture of potash salts from kelp was for a time paralyzed; its sheet anchor was once more the iodine, which from over-production had fallen in 1862 to 5s. 6d. per lb., and now gradually rose in value until, in 1872, it was sold at 34s. 8d. per lb. But now a new source of iodine—long known, but hitherto unused—was tapped. The crude nitrate of soda, or "caliche," existing on some parts of the west coast of South America, had been long reported to contain it in the form of iodate of soda, but the exact proportion was never made very clear. In 1874, however, 25 tons were exported from Peru, which, at the then price, say 11s. per lb., brought £30,800, and in 1876 the quantity had increased to 45 tons, which, at say 8s. per lb., gives £40,320. From 1877 to 1879 the price fluctuated from 12s. to 18s., and in 1880 again receded to 8s. per lb. During these years it is difficult, on account of the Chili-Peruvian war, to obtain complete statistics of the manufacture, but it may be regarded as certain that during the year 1881 about 160 tons of iodine were shipped from Peru, which, at 8s. per lb., gives a total value of £143,360; and further, that last year the quantity made would not be less than 200 tons, which, if sold in this country at last year's rates, say 6s. per lb., would bring £134,400, and the plant for its production is at present being still further increased. At first, when these large extra quantities of iodine were thrown on the market, it was thought impossible that they could be taken up, but the preparation of iodide of methyl for the manufacture of methyl violet, did much to aid the sale of iodine. This is just an example of the fact that, although over-production is sure to cripple an industry, it will, especially at a cheaper rate, increase the demand for the article through widening the circle of its application; and the potash manufacture is another instance of it.

The bromine, which is present in considerable quantity in kelp, was neglected up till about the year 1866, when it began to be extracted, but the kelp worker was not long to be allowed to enjoy even this slight advantage. Already it was being extracted from the Stassfürth liquors to some extent, and in 1872 had reached 25 tons. The price in consequence fell from 24s. to about 2s. per lb., which offered no inducement to recover it.* At the present time there are only two works in Scotland and one in Ireland engaged in making kelp products.

* Particularly as German bromine itself was suffering severely from the importation of American bromine into Germany.

I wish now to direct your attention briefly to the condition of another manufacture of perhaps even greater magnitude and importance than that of iodine and potash salts put together, namely the ammonia industry. A quarter of a century ago agriculture was dependent to a large extent upon Peruvian Guano, which was at that time very rich in ammonia, frequently containing from 15 to 18 per cent. Nearly 250,000 tons were at that time consumed in the United Kingdom, and as much more on the continent of Europe. Naturally the best deposits were worked first, and the quality gradually diminished in consequence, and now 8 per cent. or so is considered a high strength. This state of things, coupled with increasing demand for ammonia, has stimulated the production of the latter from other sources, and has been the means of advancing the price to nearly double what it formerly was, or at least from say £12 to £21 per ton. The result has been a largely increased supply which has scarcely kept pace with it, every available source being eagerly tried. The ammoniacal water obtained in the destructive distillation of shale and coal in the paraffin oil manufacture, not so many years ago was regarded as a waste product—in fact, a nuisance—but it is now not only universally utilised, but is in some instances the main source of profit. It had long been known that ammonia existed to an appreciable extent in the waste gases of blast furnaces, as it does in the gaseous products of combustion from all coals, but the mechanicol difficulties in the way of recovering it were so great that it was not attempted until quite recently, when the enterprising iron firm at Gartsherrie erected large and costly apparatus for condensing it in the form of ammonia liquor, as well as the tar which distils off from the coal in the upper part of the blast furnace. When we consider that an average furnace will consume 50 tons of coal per day, that each ton of coal burned gives 130,000 cubic feet of waste gases, that these have an initial temperature after leaving the furnace of about 500° F., and that this enormous amount of hot gas, weighing about 4 tons, contains only about 6 lbs. of ammonia, we can realise the difficulty which the pioneers of this new industry had to contend with. The result is that at present at least 1 ton of sulphate of ammonia per day is being made at these works with less than the spare waste gases from two furnaces, and it is said that the whole of the other furnaces belonging to that firm are, as quickly as possible, to be adapted for the recovery of ammonia.

But while the erection of this gigantic plant was going on, certain of the other Scotch iron-masters were not idle, and sought means of recovering the ammonia in other ways. More than one of them has experimented largely, and I believe successfully, with the object of obviating the necessity of cooling this large volume of gas, their method consisting in scrubbing the hot gases by various mechanical arrangements, with a shower of sulphuric acid, producing sulphate of ammonia at once—which, however, is of a dark colour unless much care is bestowed on it in order to keep it clean. The latest, however, with regard to the recovery of ammonia from furnace gases, is that a celebrated firm of iron-masters in this neighbourhood has secured full patent rights for fixing the ammonia by means of sulphurous or other acid in the form of vapour or gas, which, meeting with the gaseous ammonia, forms at once a salt easy of condensation and easily scrubbed with water, yielding a solution which may be obtained as high as 60° Twaddell, instead of about 4° as in the condensation method. The product consists of a mixture of hyposulphite, sulphite, and sulphate of ammonia, but it must be borne in mind that for some purposes it is not necessary that it should be in the form of sulphate at all. For the Brünner & Mond ammonia-soda process, for instance, the less sulphate the better, as when distilled with lime, in order to obtain the free ammonia, the residue in the stills will consist of a solution of the soluble hyposulphite and sulphite of calcium, instead of nearly insoluble sulphate. There is at present consumed annually in this country nearly 3,000 tons of sulphate of ammonia for the ammonia-soda process alone, and this will certainly increase, the present value being about £56,000. One great advantage of this method is that it requires no sulphuric acid, the sulphurous acid being obtained by burning, in a suitable kiln, by means of the cold blast, the waste sulphurous blaes, which can be had in Scotland by the hundred-thousand tons for the lifting. In any case, if it were required to produce it in the form of sulphate, that could be easily done by distilling with lime and receiving the evolved ammonia in sulphuric acid, as usual. This new acid vapour process is applicable to gases of every variety of furnace, with slight modifications—such as those of the Siemens' generator, Wilson's producer, gases from coking ovens, &c. It is not difficult to make an estimate of the prospective amount of ammonia from this source, at least as far as Scotland is concerned, where there are

probably at least 130 blast furnaces capable of being adapted for the recovery of the ammonia, without injury to the gases for heating purposes—such as firing boilers and heating blast. Each furnace consumes say 50 tons of coal per day, and each ton of coal is capable of yielding ammonia equal to at least 25 lbs. of sulphate. This gives for each furnace 1,250 lbs. of sulphate in the 24 hours, or 72½ tons per day for all Scotland, or for a year of 350 working days 25,375 tons, the value of which, at present rates, is nearly half a million sterling, and probably the blast furnaces working on coal in England are capable of producing as much. These enormous figures, however, dwindle into insignificance when we glance at an estimate made by Weldon, in his late lecture to the Society of Chemical Industry, of the amount of ammonia capable of being recovered from the escape gases of English coking ovens. He takes the amount of coal coked in England as approximating 20,000,000 tons per annum, which would, with a yield of 20 lbs. of sulphate of ammonia per ton, produce 180,000 tons of that salt—worth, at present, £3,500,000 sterling. It may be thought that this, if not visionary, is at any rate strictly prospective, but it is not so. Ammonia has been recovered from coke ovens in France for years past, and at Felling-on-Tyne it is being recovered in the process of coke making at the chemical works of Mr. H. L. Pattinson, under the process patented by Mr. J. Jamieson, engineer, Newcastle-on-Tyne. The whole of the waste gases of the Siemens' producers are available as sources of ammonia, but it remains to be seen whether the withdrawal of the tarry vapour from these gases by the condensation would not affect the temperature of the melting furnaces. In any cases, when plant is being erected for the condensation of ammonia, it should be well considered what process is best adapted for the purpose, for the method of to-day may not be the one of the immediate future. There is no reason why the gases from the Wilson producers should not also be utilized for ammonia, especially in chemical works, where there are always persons at hand who are supposed to be able to handle them. These producers are springing up everywhere now, and there can be no longer any question as to the economy which they effect, on account of their requiring only an inferior quality of small coal, and of their doing away almost entirely with smoke. One mistake that is being made, however, universally, is in building them too close to the point at which the gases are to be used,

leaving no room for the erection of any plant for the recovery of the ammonia.

In addition to the other means of obtaining ammonia, something is being done at present in distilling an inferior quality of dross, which is not worth more than 6d. per ton at the pit mouth, for the sake of the ammonia it yields—a coke being obtained which is worth much more than the original dross, and which will cover, besides, the cost of the distillation.

The present supply of sulphate of ammonia is obtained almost exclusively from the ammoniacal water condensed in the manufacture of coal gas and crude paraffin oil, and cannot be much short of 70,000 tons per annum for the United Kingdom.

When we consider the enormous demand for ammonia, chiefly as a fertilizer, we cannot be surprised that many attempts have been made to form it directly by the combination of nitrogen and hydrogen. It is recorded, and there seems no reason to doubt it, that when either of these gases is produced in the nascent state in presence of the other, ammonia is formed. In a paper read before the Congress of German Chemical Manure Makers, held at Hanover in June last, Mr. T. Aikman, of this town, estimated that if all the nitrogen at present used in the entire world, in the form of artificial manure, were calculated on the basis of sulphate of ammonia—the most concentrated form of nitrogen—the quantity would be approximately 500,000 tons per annum. No commerial success, however, has attended the attempts to produce ammonia by direct synthesis, although it is more than possible that that will be one day accomplished. Upwards of 30 years ago, extensive experiments were carried out, under the superintendence of Mr. Hughes, of Bo'ness, with the object of producing cyanides from the nitrogen of the atmosphere, and these were successful in so far as obtaining the product was concerned—as much as 10 cwts. per week, at one time, having been obtained—from which, of course, it would be very easy to obtain an equivalent of ammonia, by passing steam over the cyanides, at a temperature somewhat under a red heat. After an expenditure of several thousands of pounds, however, the trials were abandoned, as there seemed no hope of producing cyanides at anything like a paying figure. Mr. James Mactear has recently experimented largely with the same object, and with similar results. The process consisted in passing air, deprived of its oxygen by red hot carbon, over charcoal saturated with caustic potash, at an intense heat; but the loss of potash was

so great, that there was no hope of the method proving remunerative. It probably was reduced to potassium, which volatilized as vapour, although that explanation was not given at the time. It might be supposed that, by substituting soda or baryta for potash, and using gases such as those of the blast furnace, which had already been deprived of their oxygen, success might be achieved, as these materials cost comparatively little; but a series of experiments, extending over a period of six months, recently made by the firm to which I belong, has convinced us that the day is not at hand by which the synthesis of ammonia can be accomplished by these means. The experiments were made both on a small scale, using an iron retort of only three inches diameter, and on a large scale, with a specially constructed kiln containing a ton of alkali bricks. Both low and intense temperatures were tried, and, although cyanides were undoubtedly formed, and ammonia produced from them by steaming, the results were far from being such as to warrant the erection of more extensive plant, and the experiments were hopelessly abandoned. At first, a large quantity of ammonia seemed to be produced, but when there was deducted from this the amount evolved from the coke during the steaming, and that which was abstracted by the red hot alkali and carbon from the gases, and fixed as cyanides, there was not enough left to give the slightest encouragement to persevere further. One great drawback to this method of producing ammonia will always be the loss of alkali metal in the form of vapour, which quickly deteriorates the mixture, and finally renders it useless.

It may not be unworthy of mention that cast-off boots and shoes, which are so largely met with in the domestic refuse of our large towns, are even being regarded as a source of ammonia, although, of course, not a very extensive one. Still, when we consider that in Glasgow alone at least 500 tons of this material per annum are picked out from the town refuse, we shall see that no mean amount, over the entire country, is available, and these cast-away boots and shoes are now a regular article of commerce.

There is scarcely a chemical manufacture at the present time that is not threatened, if not assailed, from some quarter or other. It is well known that the Le Blanc process for the manufacture of soda ash from common salt has not been remunerative for several years past, a heavy loss being in point of fact incurred in the manufacture of the alkali, while little, if any profit, has been

derived from the bleaching powder. I presume nearly every one present must have perused the remarkable paper read last month by Mr. Weldon to the Society of Chemical Industry, and printed in the January number of its journal. Its subject is, "The present Condition of the Soda Industry," and it furnishes abundant food for reflection. We are there informed that the total soda compounds of every kind, comprehending soda ash, caustic soda, soda crystals, and black ash sold, calculated, in terms of pure carbonate of soda (Na_2CO_3) made in the world, is some 708,725 tons, of which 163,225 tons, or 23 per cent., are now made by the ammonia-soda process. Nineteen works in Europe and America produce this quantity of ammonia-soda, one-third of which is produced in England. The Le Blanc process, devised towards the close of the last century by the chemist bearing its name, and declared then, by a committee of inquiry appointed by the French government, to be the best method of obtaining alkali, has proved itself to be such, and has been wrought during nearly the whole of the period which has elapsed since, without any radical alteration, and without a rival. The ammonia-soda process, although known nearly half-a-century ago, was never a practical success until a considerable time after Solvay obtained his first English patent in 1863. His success lay in the apparatus which he had devised for preventing much loss of ammonia—a point of the most essential importance, considering the high price of this article. But with several millions of pounds' worth of extra ammonia salts per annum in prospect of manufacture, it is hard to say what the ammonia process may yet achieve. It is the opinion of Weldon, however—and few are better qualified to judge—that the old method will in all probability hold its own, partly through a reduction in the consumption of pyrites due to the spread of the ammonia-soda process itself, and partly on account of the introduction of Schaffner and Helbig's process for the recovery of sulphur, by which combination of circumstances the value of sulphur must inevitably be reduced—probably by one-half. The question for the present, then, stands thus:—Will the cheapened sulphur ores enable the old makers to continue the manufacture of alkali with a prospect of profit? or, will cheapened ammonia put it in the power of ammonia-soda soda makers to put alkali of high quality in the market with profit, at a lower price than their rivals? It is true the ammonia-soda process has but one leg to stand on, namely, the alkali, which is the only product; while the old process has two—the other being bleaching-powder,

which at present is lost. It is indispensable in alkali manufacture, and a good profit is what would enable Le Blanc makers to sell alkali at a low rate, especially with raw materials much cheapened—an advantage which can not be shared by their rivals who do not use them. But how long might there be a demand for bleaching powder? Discovered and patented by Tennant in the last year of last century, it has served the world till now, and has been but little improved upon. But this state of matters may not last always. Events move quickly now, and I would remind my hearers that our late Secretary—Dr Dingle—has more than foreshadowed a mode of bleaching by the direct decomposition of common salt. Were such a process to become cheap and practicable, the old Le Blanc process would receive another blow—it might be the worst of all—perhaps the final one.

Weldon is of opinion that the balance of advantage will probably rest with the latter process, and thinks it can only fail to do so through ammonia falling to half its present price, but hardly supposes that will happen. One cannot help thinking that that is a rather slender reed for the process to rest upon. We have all seen ammonia at not much over half its present price.

Apropos of the recovery of sulphur from alkali waste, a paper was read to this Section on 6th April, 1868, on that subject by Dr. Ludwig Mond, that being the inaugural meeting of the Section. He estimated then that 50,000 tons of sulphur were capable of being recovered from alkali waste in this country alone. His process consisted in the oxidation by air of the sulphur compounds of calcium in the waste, their subsequent lixiviation and the precipitation of the sulphur from them by hydrochloric acid. This process was adopted with modifications at St. Rollox works a year later, but afterwards gave place to a method devised by our late president, Mr. Mactear, who began to work it there in 1872 with a plant capable of recovering 35 tons of sulphur weekly, and of which he gave a description at the meeting of the British Association at Plymouth in 1877. It consisted in adding solution of sulphurous acid to the sulphide of calcium drainage liquor from the waste heaps, then precipitating with hydrochloric acid, by which little or no sulphuretted hydrogen was evolved. Now we are in immediate prospect of seeing a totally different mode of recovery adopted, that of Schaffner and Helbig, so ably described by Weldon in the "Journal of the Society of Chemical Industry" for February of last year, and which consists in heating the fresh waste with

magnesium chloride, by which magnesium sulphide is produced and, reacting on water, forms magnesia, while sulphuretted hydrogen is evolved quite pure and almost without loss. The sulphuretted hydrogen can either be burned, and the resulting sulphurous acid conveyed into the vitriol chambers, or one-third of it can be burned and the gaseous product mixed with the remaining two-thirds, by which the whole of the sulphur is liberated, theoretically, according to the well known reaction—

$$2H_2S + SO_2 = 2H_2O + S_3.$$

I see no reason why this reaction should not be applied to the recovery of sulphur from the sulphuretted hydrogen evolved from the cracker boxes in the distillation of ammonia liquor, especially with the improvement devised by the last-named inventors, of producing the reaction in presence of calcium chloride or magnesium chloride, by which the loss of sulphur by the formation of tetrathionic acid is prevented.

Let us now turn briefly to another class of manufactures which, as at present carried on, are perhaps as strictly chemical in their character as any of those referred to—I mean the iron and steel class. When this section was established fifteen years ago, any one who would have hinted to a Scotch iron-master that he might profit by the services of a chemist, would probably have been met with contempt, but now scarcely an iron work is without one. The introduction of Bessemer, and afterwards of Siemens' steel, necessitated the production of an iron almost completely free from phosphorus and sulphur, which the phosphatic and sulphurous carboniferous ores of Scotland could not give. By the old process of making steel from wrought-iron the phosphorus and sulphur were eliminated in the puddling process, and carbon communicated to the wrought-iron by contact with that element for a long time, at a red heat. The substitution of manganese in the two processes above referred to, for a portion of the carbon, did away with the necessity of puddling, and it then became necessary to obtain an iron, free, or at least as nearly so as possible, from the objectionable elements phosphorus and sulphur. This was only to be accomplished, for the time being, by the use of ores nearly free from these elements, such as the English hematites and the Spanish Campanil and Rubio ores. Hence enormous quantities of pig-iron, for both kinds of modern steel have been made, even in Scotland, from these ores, of which there is no better evidence

than the quantity of Spanish ore imported into Scotland, and which, according to Jenkins, amounted, in 1881, to 246,634 tons, as against 1,713,639 tons for the United Kingdom, or 68¾ per cent. of the total output. This large amount of ore is almost exclusively manufactured into pig-iron for the Bessemer or Siemens steel process, and is of course exclusive of what is made from Cumberland ore for the same purpose. But this manufacture of pure pig-iron is menaced by a process—the only one of its kind which promises success—that is the Thomas Gilchrist process, which aims at the elimination of phosphorus and sulphur from even the worst brands of pig-iron, and the question will ere long be determined whether a pure pig-iron is to be made from pure ore, for steel purposes, or whether an impure iron is to be purified to the requisite degree by the Thomas-Gilchrist methods, the inventors of which, acting on the suggestion of Mr. Gruner, Professor of Metallurgy at the School of Mines, in Paris, devised a method of treating impure iron, either in the Bessemer converter or in the Siemens' furnace, in contact with a basic lining, consisting of 3 parts of lime and 2 parts of magnesia, by which the elimination of the phosphorus and sulphur are rendered as complete as in the case of pig prepared from the purest ores—the phosphorus being in many cases reduced from 3 to ·03 per cent., or to $\frac{1}{100}$ of its original amount. It is at all times dangerous to predict with regard to any process, but if anything can give confidence in a new one it is its rapid spread and wide adoption in a short space of time, and these elements are not wanting in the basic process. The following figures, which Mr. Gilchrist has had the goodness to supply me with, show the total output of basic steel for the month of October, 1882:—England, 9,578 tons; France, 1,240 tons; Belgium, 1,687 tons; Germany, 23,088 tons: Austria, 7,760 tons; Russia, 1,270 tons—total in Europe, say 47,633 tons, which equals an annual make of 571,596 tons. There are 9 converters in England and 25 on the Continent being built to work the process, with an estimated annual output of 624,000 tons, which will bring the total make up to 1,195,500 tons. No more need be said for the confidence which is being placed in the basic process.

It is perhaps worthy of note in passing that there is no possibility of distinguishing chemically between Siemens' and Bessemer steel, although I am informed by one well qualified to judge, that the former, when made for the same purpose as the latter, contains,

as a rule, a little more carbon. Some varieties of soft steel, again, approach so closely in composition to that of malleable iron that it is scarcely, if at all, possible to distinguish between them.

Glancing for a moment at a very different kind of manufacture we see changes not less revolutionary. When this Section was instituted, madder and its product—garancine—were exclusively used for the dyeing of turkey red. Artificial alizarine had not as yet been discovered.

At a meeting of this Section, held in the Andersonian Buildings on 15th March, 1869, Mr. W. H. Perkin, F.R.S., himself the discoverer of the first aniline dye—and afterwards an extensive manufacturer of artificial alizarine, read a paper entitled "Observations on some Colouring matters." During the discussion which followed, that gentleman was asked by a member present whether he had seen it intimated in a certain German chemical periodical, that alizarine had been obtained artificially from anthracene. He replied that he had not. The discovery referred to was the celebrated one of Græbe and Liebermann. The sequel you know. There is now practically no madder or any derivative of it used in the dying of turkey red, and work can be done with the artificial article, which the natural could not have approached. It is to be deeply regretted that this manufacture was to so large an extent allowed to take root and grow out of this country. The result has been, besides others, a partial, although only temporary, stoppage of the turkey red industry in this locality, and the loss of the profit contingent upon the manufacture of all the alizarine used in this district, the value of which cannot be much short of £200,000 per annum.

It is scarcely necessary to give further examples, of the progress which the chemical trades have made during the last few years. It is recorded in the minutes of the meeting of the Glasgow Philosophical Society for November, 1868, that Mr. John Mayer "exhibited a specimen of Nobel's Giant Powder or Dynamite, and described the method of its application." Some idea of the progress made in this department of chemical manufacture may be gained from the fact that, last year, one factory alone in this country made 1,300 tons of this material (in addition to what was produced by seven factories on the Continent of Europe and in America), and plant is being built which will nearly double this quantity. One would have thought, with an agent like this, which contained so much latent energy as compared with any of its predecessors, that

every possible requirement would be satisfied; but the demand for improvement is never satisfied, and with the real demand, sooner or later, must come the supply. When nitro-glycerine was used in the liquid form as a blasting agent its employment was attended with great risk, from the fact of its fluidity. Nobel's simple but highly practical method of absorbing it into porous silica served every purpose of safety, but reduced its energy by the introduction of 25 per cent. of inert matter. Two years ago the same restless inventor entirely overcame this objection, by mixing 93 per cent. of warm nitro-glycerine with 7 per cent. of nitro-cotton, the latter being completely dissolved, and the mixture or rather compound yielding, when cold, a stiff jelly, which contains at least the full latent energy of nitro-glycerine itself.

Wherever we turn we are met by inventions and innovations, and one great feature of our time is that much attention is being paid to waste products and to waste heat, as well as to waste energy generally. How much heat was formerly lost from our blast furnaces that is now utilized? How much still remains unused that might be employed for a variety of purposes? In the south of France common salt, muriate of potash, Glauber's salts, and other products, are obtained by the evaporation of sea water—partly spontaneous, of course. What is to hinder the waste heat from some of our blast furnaces, such as those of Ardeer, Eglinton, Glengarnock, and Kinneil, from being applied to the recovery of the treasures of the sea? I estimate that there is as much heat at present being absolutely wasted from these 4 furnaces alone as would produce 10,000 tons of common salt, 300 tons of muriate of potash, and 2,000 tons of Glauber's salts per annum; but there is nothing to hinder sea water being pumped to any great iron-making centre, such as that of Coatbridge. Here, then, would indeed be a field for the manufacture of ammonia-soda, with both brine and ammonia on the lowest possible terms. Iron-masters may laugh, but I can assure you that, ten years ago, they would have ridiculed quite as much the idea of making sulphate of ammonia in an iron work as they could possibly do the production of soda and potash salts.

In short, the time has gone past when objections to the adoption of a supplementary manufacture can be raised on the ground that it is incongruous or not in keeping with the existing one, and I have no doubt the most of us will live to see some combinations in that respect, which at present are not even dreamed of.

XXI.—*Notes on Nitro-glycerine, Dynamite, and Blasting Gelatine.*

By GEORGE M'ROBERTS, F.C.S.

[Read before the Society, 25th April, 1883.]

WHEN I began the preparation of this article, I had to consider whether I should give you a brief *resumé* of what is known of nitro-glycerine and its preparations, or select some branch of the subject, and give it a fuller treatment. After due consideration, I have deemed it best to glance at the subject all round, selecting here and there a few points for fuller discussion. It is impossible, in the limits assigned to this paper, to do more.

I do not intend to give a history of the introduction of nitro-glycerine, nor of its applications in blasting; but I shall, as briefly as possible, refer to some of its properties. It will be of interest, however, if, first, I give a short account of the method of manufacture as followed at most of the factories associated with the name of Mr. Nobel.

Nitro-glycerine, which has been known to chemists since 1847, has been of practical importance only since 1863. It is readily prepared on a small scale by dropping glycerine into a mixture of strong nitric and sulphuric acids, the whole being kept at as low a temperature as possible. That, in fact, was the method followed by Sobrero, who discovered nitro-glycerine in 1846. But on the large scale upon which a manufacturing operation has to be conducted, such a method is inapplicable. The acids are first mixed together and cooled, by means of cold water and by agitation with compressed air. They are then run into a large leaden apparatus, which is kept cool by being surrounded with cold water, and by running cold water through leaden worms, which coil round the interior of the apparatus. When the acids have fallen to a low enough temperature, glycerine is injected into the mixture by means of compressed air, driven through a peculiar

kind of injection apparatus. The glycerine enters the acids in a fine spray, and is immediately nitrated. Considerable heat is developed during the process. A delicate thermometer, graduated to tenths of a degree centigrade, dips into the mixture of acids and nitro-glycerine, and is carefully watched by an attendant during the operation. The temperature is thoroughly under control by the admirable means adopted, and it is never allowed to exceed at any part of the operation a certain fixed limit. Apart altogether from the danger of allowing the temperature to become too high, it is found that when it exceeds the limit assigned other bodies than nitro-glycerine are formed, and there is a corresponding loss of nitro-glycerine. The end of the nitration is made known at once to the attendant by the fall of the thermometer, and when the temperature has descended to a certain degree, the contents of the nitrating apparatus, amounting to about 4 tons of acids and nitro-glycerine, are run off into another leaden tank in a separate building, in which the mixture is allowed to stand for some time. The nitro-glycerine being of less specific gravity than the mixed acids, and being insoluble in them, immediately commences to separate, and in a short time—generally in about an hour—the separation is complete. The nitro-glycerine is then drawn off and washed in water, and the mixed acids are transferred to a settling tank, where any globules of nitro-glycerine remaining in the acid come to the surface, and are subsequently removed. The acids are preserved for further treatment, and are again utilised in the manufacture. The nitro-glycerine, after copious washing with water, is finally washed in an alkaline solution, until every trace of free acid has disappeared. It is then carefully filtered into another tank, in which it is stored until required for conversion into dynamite. Throughout every part of the process, the operations are carefully superintended by an experienced chemist and by a foreman, as any abnormal increase of temperature, or any deviation from the routine method of working, might be followed by an accident. The arrangements and discipline are so good, however, that until now there has been no fatal accident in the nitro-glycerine department at Ardeer.

As may be readily understood, all the materials used in the manufacture require to be the best of their kind. The sulphuric acid is the purest and most highly concentrated it is possible to obtain in commerce. The nitric acid is manufactured at Ardeer. It is of a uniform gravity of 1·50, and is of a pale straw colour.

The nitrate of soda, from which the nitric acid is obtained, never contains more than ·5 per cent. of chlorides, and seldom so much. The glycerine is practically anhydrous. It is of 1·26 specific gravity, and is free from lime, iron, alumina, chlorides, and fatty acids. The presence of iron and alumina, either in the glycerine or in the acids, is found seriously to interfere with the separation of the nitro-glycerine. A similar remark applies to chlorine. If the acids are not of the highest gravity, there is an immediate falling off in the yield of nitro-glycerine; but when they are kept of uniformly high gravity, and good glycerine of 1·26 specific gravity is regularly used, the yield of nitro-glycerine is astonishingly regular. The specific gravity of the mixed acids before the introduction of the glycerine is found to be about 1·76. After the separation of the nitro-glycerine, it is 1·73, and those acids contain about 11 per cent. of the oxides of nitrogen, all capable of reconversion into nitric acid. The chemical reactions in the conversion of glycerine into nitro-glycerine may be thus shown—

$$\begin{matrix} C_3H_5O_3 \\ H_3 \end{matrix} + 3HNO_3 = \begin{matrix} C_3H_5O_3 \\ 3(NO_2) \end{matrix} + 3H_2O.$$

The water formed during the process is taken up by the sulphuric acid.

From this equation, it appears that one part of glycerine ought to yield 2·46 parts of nitro-glycerine, but in practice only 2 parts are obtained for 1 of glycerine as a rule. On the working scale it may be broadly stated that 1·2 tons of nitric acid of 1·5 specific gravity, and 2 tons of sulphuric acid of 1·84 specific gravity, and $7\frac{1}{2}$ cwts. of glycerine, of 1·26 specific gravity, yield 15 cwts. of nitro-glycerine. The reason of this smaller yield, no doubt, is that in the process of nitration a number of obscure nitro bodies are formed, which are washed away in the subsequent operations.

Nitro-glycerine is a dense, oily fluid. When pure, it is colourless as water; but as obtained on the commercial scale it is of a pale brown colour. Its specific gravity is 1·6. It is soluble in all proportions in acetone, acetic ether, aldehyde, acetic acid, nitric acid, benzol, nitro-benzol, ether, and a mixture of ether and alcohol, and in chloroform. It is soluble in 1·75 parts methylic alcohol, and 2·8 parts absolute alcohol; sparingly soluble in sulphuric acid, amylic alcohol; and practically insoluble in water and carbon disulphide. The solution of nitro-glycerine in wood spirit renders the former inexplosive; and Mr. Nobel

before the invention of dynamite, recommended that method of rendering nitro-glycerine safe for transport. It was soon discovered, however, that the use of wood spirit had many drawbacks. It was very troublesome to the miner, because, before he could use the nitro-glycerine, he had to wash out the wood spirit, thus causing loss of time. In cold weather, too, it was found that the nitro-glycerine crystallised out, and had then to be thawed for use, making it as unsafe as without wood spirit. That plan of making nitro-glycerine safe was therefore soon given up.

Nitro-glycerine crystallises at about 40° F. in six-sided prisms, and exposure for a considerable time even to a temperature of 50° F. is required before it again assumes the liquid form.

Nitro-glycerine, when pure, may be kept any length of time without decomposition, Until lately, I had a sample of it nine years old, which had undergone no deterioration during all that time.

Previously to the invention of dynamite, the use of nitro-glycerine as a blasting agent had become very extended. Mr. Nobel's factory in Sweden was kept busily employed to meet the demand which had arisen for the new explosive agent. It was packed for transport in tin cases containing about 40 pounds weight of the explosive. It occasionally happened that these cases leaked in transport; and an instance is on record in which a leaking tin of nitro-glycerine was successfully soldered at Rotterdam by a working plumber, without emptying the case. The danger of such a packing was enormous, because, in almost every instance in which a case was allowed to fall on the ground from the height of even a few feet, an explosion occurred. Mr. Nobel says—"A tin cartridge filled with nitro-glycerine causes no explosion if it drops from a height of several hundred feet on soft ground; yet that same cartridge, falling only three feet on an anvil, bottom foremost, is sure to set the charge off, though there is not a particle of the explosive on the outside. Nitro-glycerine contained in a wooden barrel, headed with wood, would be as safe against all ordinary concussion as if it were common oil; the only danger could spring from leakage, which might expose it to a direct blow, but even that must be uncommonly strong to become dangerous unless produced by two hard, sonorous bodies striking against one another. When canisters to hold nitro-glycerine were first adopted, its sensitiveness to vibration was very imperfectly known, and the square form easily given to a metallic receptacle was

necessary to allow for the expansion of nitro-glycerine at the moment of its crystallisation, when, like water or glycerine, it bursts a cylindrical vessel in which it is contained. Later on the full extent of the danger only made itself too well known through fearful accidents, caused in most instances by gross carelessness in dealing with it, but proving not the less that it could not, without material alteration, remain an article of commerce." The numerous accidents in transport had such an effect on the public of this country and on the Government, that, in 1869, the nitro-glycerine Act was hurried through Parliament, which finally excluded nitro-glycerine, so far as this country was concerned, from the list of commercial articles.

Nitro-glycerine has a sweetish pungent taste. It produces intense headache in those who handle it for the first time. The headache is accompanied by diminished action of the heart, cold of the extremities, nausea, and vomiting. A nitro-glycerine headache is one of the worst possible; but, curiously enough, if the person affected by it continues to handle the explosive material, the headache, in the course of a day or two, disappears and does not recur. The workmen who work with nitro-glycerine every day never have headache, and are, in fact, remarkably free from diseases of any kind. Of late, nitro-glycerine has been used in medicine for certain diseases of the heart, and notably in *Angina Pectoris*, with good results.

When nitro-glycerine is spread in a thin layer on an unyielding metallic surface, and is exposed to the blow of a hammer, it explodes more readily than even fulminate of mercury under similar circumstances—that is, fulminate of mercury requires a harder blow to explode it than does nitro-glycerine. When nitro-glycerine is in a crystallised state it is not so liable to explosion as in the liquid form. This is contrary to the general public belief. As a matter of fact, I have seen pieces of frozen nitro-glycerine thrown with great force and shattered against an iron plate without producing explosion; and miners in America and in Austria have been known to break up blocks of frozen nitro-glycerine by means of a pick. In fact, in the United States, where nitro-glycerine in the liquid form is recognised as the most useful explosive, it is now frozen in the tins before leaving the factory, and in that condition it is transported in perfect safety to its destination. Thoroughly frozen nitro-glycerine cannot be got to detonate even with a detonator containing so much as 1 gramme of fulminate of mercury;

whereas, when unfrozen, a detonator charged with the tenth-part of a gramme is sufficient to explode it. The popular belief in the extreme danger of frozen nitro-glycerine has possibly arisen from erroneous reports as to the causes of certain nitro-glycerine accidents.

When nitro-glycerine is thrown on a hot metal plate, its behaviour depends on the temperature of the metal. If the plate has not attained the heat of redness, the nitro-glycerine lies a short time and then explodes. If the temperature is a little higher, it goes off in red fumes; and if the plate is red-hot the nitro-glycerine takes fire and burns away. The temperature at which nitro-glycerine explodes is usually stated to be between 380° and 400° F. The experiments to ascertain the exploding point have not been very precise, but an explosion can be brought about by merely heating the nitro-glycerine to a point where decomposition sets in. The decomposition itself speedily raises the temperature to the point of explosion.

Nitro-glycerine, and the various explosive mixtures of which it forms a part, would have been of little use in blasting had it not been for the discovery of a ready means of effecting their explosion. Mr. Nobel has explained the reasoning by which he was led to the discovery of the special method of *detonation*, which is now in use. He had observed that when a hammer strikes an anvil on which there is a thin coating of nitro-glycerine, if the blow is light the nitro-glycerine explodes only under the hammer, just where it receives the blow; but if the stroke is a heavy one, the whole coating of nitro-glycerine explodes. He reasoned thus:—The blow of the hammer produces a strong compression of the liquid and raises its temperature to the exploding point, and if I can, by means of a local detonation, give a blow and raise the temperature of the nitro-glycerine locally, as is done by the blow of the hammer, an explosion must follow. Thus reasoning, he was led to try strongly-confined detonating mixtures, and eventually found that the detonation of nitro-glycerine could be rendered certain by using a kind of strong copper cap charged with fulminate of mercury. The spark which sets off the powder in the detonator was conveyed to it by means of an ordinary safety fuse. Specimens of the detonators and fuse are here shown.

Having thus briefly alluded to nitro-glycerine, I now proceed to consider it in the form of dynamite, by which it is so modified in its physical condition that it is rendered comparatively safe

to use, and is certainly free from many of the objections that were urged against the use of nitro-glycerine. Dynamite may be defined as nitro-glycerine absorbed in porous substances. Those substances may be explosive or not. In the first dynamite charcoal was used as the absorbing material; then sawdust was tried, brick-dust, paper, rags, and numerous other materials. Finally, the substance known as kieselguhr, or earth meal, was fixed upon by Mr. Nobel as the best absorbent. Kieselguhr is found in many countries. It is the mineral remains of a kind of moss that grows in stagnant water. The stem consists chiefly of silica; and, when the organic substance of the plant decays, the silicious part remains, and retains the shape it had when it formed a portion of the plant—that is, a kind of tube. Beds of kieselghur are found in Aberdeenshire, where they form, in some cases, the bottoms of peat mosses, and it is from that source that Ardeer derives some of its supplies. Kieselghur absorbs three or four times its weight of nitro-glycerine, and has this advantage over other absorbents that it retains the nitro-glycerine under considerable pressure. At Ardeer the raw kieselghur is calcined in a peculiar kind of kiln to drive off water and organic matter. What remains after calcination is ground and sifted to remove sand, and only that which passes through the sieve is used in the manufacture of dynamite. An analysis of it gives about 98 per cent. of pure silica. There are traces of lime and iron. The kieselghur, thus prepared, is used in the proportion of 25 per cent. of kieselghur to 75 per cent. of nitro-glycerine. The resulting product is a reddish brown, moist powder. The specific gravity of dynamite varies from about 1·59 to 1·65. When set fire to with a match or fuse, it burns quickly, with a yellowish flame, giving off nitrous fumes. Large quantities can be thus burnt without explosion; but eventually a point is reached when the unconsumed mass becomes heated by the combustion of the rest to the point of explosion, when, of course, it instantly goes off. As a rule, dynamite freezes at about 40° Fahr.; but it is a rule not without exception, as I have found unfrozen cartridges, in the middle of winter, lying in the boxes alongside of completely frozen cartridges. When dynamite is frozen it burns very slowly, because it has to thaw before burning; and, if a burning cartridge be watched, it will be seen that the thawing of the cartridge goes in advance of the combustion by about 1-16th of an inch only. The burning being thus very slow, a portion of the dynamite gets heated up to

the explosion point before the fire can reach it, and an explosion follows, in some cases before 4 or 5 cartridges can be consumed. I have more than once got an explosion by making a pile of eight frozen cartridges, and lighting the bottom one. Before they were all consumed an explosion occurred. Professor Abel has offered the following explanation of this phenomenon. He supposes that the cartridges are not uniformly frozen throughout, and that strongly frozen portions enclose parts less frozen, and that the heat of combustion raises one or other of the less frozen parts to the exploding point before the hard frozen outer part has begun to thaw. Pressure is thus developed sufficient to cause an initial detonation, which immediately sets off the remainder of the dynamite.

When a rifle or pistol bullet is fired through a mass of dynamite, whether in a packing-case or spread out loosely in the open air, an explosion follows instantly; but when the cartridges are frozen, a rifle bullet may be fired through them without causing explosion. The ordinary detonator does not explode thoroughly frozen dynamite, although one-tenth part of the detonator charge is sufficient to set it off when the dynamite is not frozen. It is thus seen that frozen dynamite is safer than unfrozen dynamite, in so far as it is more difficult to explode, and in that respect it resembles nitro-glycerine.

When frozen dynamite is laid on a steam pipe or near a fire, to thaw, there is risk of a portion of it becoming heated to the exploding point before the whole of the cartridge has become thawed, and great care has to be exercised to avoid overheating. It is safely and readily thawed by heating it in a water oven, the water of which is at a temperature of 80° to 100° Fahr.

The chemical reaction and the resulting products from the explosion of nitro-glycerine may be thus shown—

$$\begin{matrix} 2(C_3H_5O_3) \\ 3(NO_2). \end{matrix} = 6CO_2 + 6N + 5H_2O + O.$$

It is thus seen that every molecule of nitro-glycerine has half an atom of oxygen to spare over and above what is required for the oxidation of the carbon and hydrogen contained in itself. This oxygen is utilized in the new explosive (also an invention of Mr. Nobel's) called blasting gelatine.

Blasting gelatine is the latest nitro-glycerine preparation that has been brought before the public, and it merits more than a

passing notice. It consists of nitro-glycerine, incorporated with a mixture of mono- and bi-nitro-cellulose. The nitro-cellulose, if it is free from unnitrated cotton and from tri-nitro-cellulose, readily dissolves in the nitro-glycerine, with the aid of heat, forming with it a viscid substance, somewhat elastic, and semi-transparent.

In preparing blasting gelatine 93 parts (by weight) of nitro-glycerine are taken, and 7 parts of nitro-cotton. The nitro-glycerine is heated by the aid of water at 50° C., and the nitro-cotton, in a fine state of division, is added to it in small portions at a time, the whole being kept in agitation by means of mechanical stirring. The temperature is never allowed to exceed a certain limit, because, owing to the heating and mixing being done in a copper vessel, small rises of temperature beyond the fixed limit would lead to danger. That limit is 35° C., at which the nitro-cotton is perfectly soluble in nitro-glycerine, and at which the operations can be safely carried on. As the stirring proceeds, the nitro-cotton and nitro-glycerine gelatinise, and in the course of an hour the material forms a homogeneous mass, somewhat resembling thin dough in consistency. As it cools, the blasting gelatine becomes stiffer, and assumes a semi-transparent aspect. During the whole process the thermometer has to be carefully watched, as the range of safety is not a great one, and any carelessness on the part of the chemist or the foreman in charge, might result in an explosion. The manufacture is thus attended with considerable difficulty and danger; but once made, blasting gelatine is the safest of explosives.

At low temperatures blasting gelatine freezes into a hard, whitish solid of crystalline structure; but the exact temperature at which freezing takes place has not been ascertained, as cartridges are sometimes found to resist freezing for 24 hours, although kept during that time in a mixture of ice and salt. Other cartridges are found to freeze readily at about 35° to 40° F. Frozen gelatine is, in some respects, more easily exploded than unfrozen gelatine. A rifle bullet can be fired through any number of unfrozen gelatine cartridges without exploding them, but when a shot is fired similarly through frozen cartidges they never fail to go off. In this respect blasting gelatine behaves exactly the reverse of dynamite. The transmission of detonation through blasting gelatine when unfrozen is much more slow than through either nitro-glycerine or dynamite, but when the cartridges are frozen the detonation appears to be quite as rapid as in dynamite. The

comparatively slow detonation of blasting gelatine is of great use in blasting mild or soft rock, as the crushing action of a slow explosive is not so violent as that of a quick explosive, but the rending effect is greater if the explosive is well confined, and the rock can thus be blasted in larger blocks. Blasting gelatine cannot be exploded in trains in the open as dynamite can, so that for certain engineering purposes it will never supersede dynamite. It explodes readily when confined in boreholes, no matter what may be the size of the charge. It is now rapidly superseding dynamite in various mining operations.

Blasting gelatine is insoluble in water, in which it may be kept any length of time without deterioration. Its specific gravity is 1·55 to 1·59. It is soluble in acetic ether, acetone, aldehyde, and ether alcohol. Blasting gelatine may be looked upon as a perfect explosive, because on explosion it is resolved entirely into CO_2, H_2O, and N, there being just enough of O in it to combine with the C and H.

As blasting gelatine is insoluble in water, and is not in any way affected by it, it must come to be of great use eventually in sub-aqueous blasting. Dynamite is subject to the disadvantage of parting with its nitro-glycerine if it is allowed to remain for an hour or two under water, but blasting gelatine may remain submerged for months, and it will then blast as effectively as when first put into the hole.

It has been lately sought to use blasting gelatine in shells, but the material in its present form does not appear to be well adapted to such a purpose. In order to render it less sensitive, so that the shell might be fired from the gun without risk of exploding the charge, the gelatine had incorporated with it about three to five per cent. of camphor. The camphor had the effect of rendering the gelatine so insensible to shock that even the blow of the shell against an iron target failed to set it off, and the gelatine was gathered up in bits all round the target. The effect of increasing the proportion of nitro-cotton in gelatine, and diminishing that of nitro-glycerine, is to lessen its sensibility to explosion; and gelatine made tough with 9 or 10 per cent. of nitro-cotton cannot be got to explode with a detonator containing 12 grains of fulminate of mercury and chlorate of potassium. On the other hand, when gelatine is made of a viscid consistency—such that when a cartridge, deprived of its wrapper, is allowed to stand on a porcelain plate, and begins to spread itself out, the ordinary

detonator in use for exploding dynamite never fails to explode it. The relative sensibility to detonation of blasting gelatine, as compared with dynamite, has been carefully ascertained at Ardeer by numerous experiments. It is found that while No. 1 dynamite can be unfailingly exploded by a detonator charged with 0·8 grains of cap mixture, the minimum quantity required to explode the best blasting gelatine is 3 grains; and that if the gelatine is tough (that is, if it contains an extra proportion of nitro-cotton) it fails to detonate completely even with a 12-grain charge of cap composition. As those experiments have been done under the most favourable conditions—(that is, the cap composition placed in actual contact with the explosive), it is necessary—to get unfailing explosions with tough blasting gelatine—to use in actual mining, a detonator with at least one gramme, or 16 grains, of cap composition, or the charge would have to be set off by a dynamite primer.

It is of great advantage to manufacturers of explosives to be able at any time to test their comparative power for blasting, and various methods have been adopted from time to time with that object. Some experimenters use a mortar fixed permanently on a strong bed, at an angle of 45° with the horizon, and they use weighed charges to propel the mortar shot. The distance thrown is regarded as the test of the strength. That method gives tolerably good practical results, but it is subject to many inconveniences.

For a considerable time back I have adopted a new and a better method, which gives fairly good results, without the inconvenience of the fixed mortar, and I shall now describe it. A cast-iron mortar, weighing about 600 lbs., is suspended by light iron rods in a powerful frame. The distance between the points of suspension and the centre of the trunnions is exactly 10 feet. The bearings are very accurate, and the mortar swings so easily that a very slight push is sufficient to move it. The bore of the mortar is set permanently horizontal. The projectile fits the bore gas-tight. Behind the chamber for the projectile there is a small recess to receive the explosive. When a shot is fired the projectile, which weighs about 40 lbs., is driven forward, while the mortar itself swings back. It carries with it a pencil, which marks on a graduated index the angle of its flight. The effect in work done by the shot is the raising of the mortar through the versed sine of of that angle, multiplied by 2; because the work in throwing the shot is equal to that done in raising the mortar. The angles have been all calculated, and the work done in raising the weight

through the versed sines of those angles reduced to foot pounds, and marked on a board on the framework of the mortar, so that the assistant who fires the shots has only to note the angle and read off the foot pounds for every shot he fires. The work of testing is thus easily and quickly done. With that apparatus it has been found that the effective power of the undernoted explosives is as given below, using a charge of 10 grammes, and firing in every case by means of a fuse and detonator :—

	Foot Pounds.
Blasting gelatine, consisting of 93 per cent. of nitro-glycerine and 7 per cent. of nitro-cotton,	1,400
Nitro-glycerine,	1,270
No. 1 dynamite,	900
No. 2 dynamite, consisting of 18 parts of nitro-glycerine, 71 parts of nitrate of potash, 10 parts of charcoal, and 1 part paraffin,	531
Westquarter Factory mixture for detonators, consisting of 70 parts fulminate of mercury and 30 parts $KClO_3$,	481
Gun-cotton,	462
Fulminate of mercury,	307
Curtis & Harvey's extra strong gunpowder,	272

NOTE.—*The reason, no doubt, why the gun-cotton shows so poorly in this table is that its explosion in the mortar was imperfect.*

A mortar test can give no accurate scientific indication of the heat or tension of the gas evolved, or of the total force of an explosive; but it gives, in a fairly accurate way, the measure of the total practical effect likely to be got in blasting. Hence its utility to manufacturers.

The method of testing explosives described above is applicable only to those that detonate, or, in other words, to those explosives whose conversion into gas is practically instantaneous. If the explosive is a slow one, such as gunpowder, the projectile may have escaped from the mortar before the whole charge is consumed, but with detonating mixtures the explosion is so rapid that there can be no doubt that the conversion into gas is complete even before the projectile has begun to move. The explosion of a charge of dynamite, for instance, does not occupy more than the 20,000th part of a second.

We are indebted to Professor Abel and Captain Noble for making known to us the velocity with which explosion is transmitted through gun-cotton, dynamite, and nitro-glycerine, and certain other explosives. The chronoscope of the latter gentleman,

which was the measuring instrument used, showed that explosion is transmitted through trains of dynamite at the rate of 20,000 to 24,000 feet per second.

At this rate the explosion of a cartridge a foot long must only occupy the 24,000th part of a second. A ton of dynamite cartridges of the usual size—about $\frac{7}{8}$" diameter—laid end to end in a line would stretch a mile, and the whole train could be exploded in the one-fourth part of a second by firing a cartridge at either of the ends. If fired in the middle of the line the explosion would be transmitted both ways, and would occupy only the eighth part of a second. The facility with which dynamite can be fired in trains offers great advantage in many engineering operations, such as where it is required to blow down an arch or a wall. It is enough to lay a train of cartridges along the crown of the arch, or along the bottom of the wall, and explode one cartridge in the usual way with a detonator. The whole train goes off instantly.

The enormous velocity with which dynamite explodes explains the great violence of its action, and the tremendous local rupturing effects of even small quantities of it exploded in the open, and without being enclosed in a case of any kind. The detonation of a cartridge in the 24,000th part of a second must produce an enormous instantaneous pressure on the spot on which it explodes. For such a sudden explosion the pressure of the atmosphere itself is sufficient tamping.

The increase in the demand among miners for strong explosives is very remarkable. Since 1867 the annual sales of dynamite from the factories with which Mr. Nobel is associated have been as follows:—

In 1867	11 Tons.		In 1875	3,500 Tons.	
1868	78	,,	1876	4,300	,,
1869	184	,,	1877	5,500	,,
1870	424	,,	1878	6,200	,,
1871	785	,,	1879	7,000	,,
1872	1,350	,,	1880	7,500	,,
1873	2,050	,,	1881	8,500	,,
1874	3,120	,,	1882	9,500	,,

The last two years have been estimated, as there are no precise figures to go by. The sale of such a large quantity of explosives indicates a considerable amount of mining activity. Besides the factories with which Mr. Nobel is connected, numerous others

have sprung into existence, notably in Germany and in America. In Austria, dynamite is no longer manufactured, as there is no demand for it, its place having been taken by blasting gelatine.

It is unfortunate that in this country the manufacture and sale of explosives is hampered to a hurtful degree by legislative restrictions. Some restriction is no doubt necessary, but in this country restriction amounts in some cases almost to prohibition, if a new explosive is to be introduced. As the law now stands, if a manufacturer discovers a new explosive, or a new explosive mixture, he cannot make working trials of it without the consent of the Home Office, and without having submitted samples for the approval of the Home Office Chemist, to whom, as a matter of course, a fee must be paid. This regulation must interfere with the introduction of a new invention, because no man will care to pay fees for the examination of an explosive which, when it comes to be tried, may not take with the public after all. Abroad, although there are restrictions affecting explosives, there are no such onerous impediments as we have here: hence foreign chemists and manufacturers have an advantage over us in that respect.

Accidents in the use of nitro-glycerine preparations have been very numerous, but it appears that their proportion to the number of persons using explosives is decreasing every year. That is no doubt partly owing to the greater experience in their use. But although the use of those explosives has been attended by a considerable number of accidents, Mr. Nobel has pointed out that it has also been accompanied by a considerable saving of life. Mr. Nobel says that that saving is due, firstly, to safety from fire where small quantities are dealt with; and, secondly, to the absence of danger in loading boreholes, since there is no longer any need for tamping; and, thirdly, to the great reduction in the number of workers required for doing the same work as with gunpowder. By far the greater number of accidents in mines is due to causes quite independent of the use of explosives, and it is evident that their number will be reduced in the same ratio as the number of hands is reduced.

Until last year the factory at Ardeer was the only one in Great Britain at which nitro-glycerine explosives were produced, but now there are at least two other factories in course of erection in England, and one of those already in a position to manufacture. The demand for nitro-glycerine explosives is likely to go on increasing for a considerable time to come, so that there is no fear of the

market being overstocked even were there more factories in existence. New outlets are being found every day, and the difficulty would appear to be to produce enough of such explosives to meet the demand.

From the foregoing it will be seen that of the three explosives—nitro-glycerine, dynamite, and blasting gelatine—the latter is the safest in every respect as regards handling, transport, and storage.

I have thus as briefly as possible made reference to some of the properties of nitro-glycerine, and the two chief of its preparations. There has been time merely to give a kind of catalogue of properties without enlarging on any of them. Some of the points passed over are worthy of better treatment, and possibly on a future occasion I may have the honour of reading a paper on them.

XXII.—*On the Action of Heat and the Chlorides of Phosphorus upon the Watersalts of Hypophosphorous, Phosphorous, and Phosphoric Acids.*

By Otto Richter, Ph.D.

[Read before the Chemical Section, 2nd April, 1883.]

From a careful comparison of the old system of notation with his own, the author has satisfied himself that the principal molecular changes which take place in a given reaction may also, with equal clearness and precision, be expressed by means of that old system. He therefore has bethought himself of provisionally adopting the same as a familiar and suitable medium for rendering the said molecular changes sufficiently plain and intelligible. Again, as regards the process of molecular substitution, which plays such a conspicuous part in almost every kind of chemical reactions, the author would refer the reader to a little pamphlet entitled the "Typo-Nucleus" Theory,* where the working of that process is fully described and illustrated. With these preliminaries the author then proceeds to the discussion of the

First Part

of his programme, which treats on the principal molecular changes attending the action of heat upon the watersalts of hypophos phorous, phosphorous, and phosphoric acids. Let us bear in mind, first of all, that the watersalts of these acids are formed by the substitutional action of one, two, or three molecules of water upon the acids in question. In the first place, a mol. of hypophosphorus acid, P_4O_2, by combining with one mol. of water, H_2O_2, gives rise to the first hydrate, $P_4 - 2(HO_2)$. This compound is then speedily made to split up into two mol., $P_2 - HO_2$, from which the second hydrate, or bibasic hypophosphite of water, is formed, according to the equation $P_2 - HO_2 + H_2O_2 = (P_2 - H) - 2(HO_2)$.

* Recently published by Messrs. Maclachlan & Stewart, South Bridge, Edinburgh.

Under the influence of heat two mol. of this watersalt are found to resolve themselves into a mol. of phosphoretted hydrogen gas and a mol. of the ordinary tribasic phosphate of water, where the molecular changes are as follows:—In the first stage one of the two conspiring hypophosphites splits up into $P_2 - HO_2$ and a mol. of H_2O_2. The former molecule, after merging into the isomeric modification, $P_2O_2 - H$, surrenders its oxygen to the remaining mol. of hypophosphite of water, with formation of the mol., $P_2O_2 - H - 2(HO_2)$, which soon passes into the ordinary tribasic phosphite of water, $P_2 - 3(HO_2)$, while $P_2 - H$ remains. In the second stage the newly-formed water-molecule, by ceding its oxygen to the phosphite and its hydrogen to the mol., $P_2 - H$, gives rise, finally, to a mol. of the ordinary tribasic orthophosphate of water, $P_2O_2 - 3(HO_2)$, and a mol. of phosphoretted hydrogen gas, P_2H_3. In the second place, a mol. of phosphorous acid, P_4O_6, by combining with one mol. of water, gives rise to the first hydrate, according to the equation. $P_4O_6 + H_2O_2 = P_4O_4 - 2(HO_2)$.

This compound soon resolves itself into two mol., $P_2O_2 - HO_2$, each of which, by combining with a mol. of water, engenders a mol. of phosphite of water, $P_2 - 3(HO_2)$. Under the influence of heat four mol. of this watersalt give birth to three mol. of orthophosphate of water and one mol. of phosphoretted hydrogen gas. In this metamorphosis one of the four conspiring phosphite of water molecules breaks up into $P_2O_2 - HO_2$ and H_2O_2. The former of these, then, supplies the oxygen for the conversion of two mol. of phosphite into two mol. of phosphate, while $P_2 - H$ remains. Finally, the newly-formed water-molecule, by yielding up its oxygen to the third mol. of phosphite, and its hydrogen to the mol. $P_2 - H$, engenders the third mol. of phosphate and a mol. of phosphoretted hydrogen gas.

In the third and last place, a mol. of phosphoric acid, P_4O_{10}, by combining with a mol. of water, gives rise to the first hydrate, according to the equation $P_4O_{10} + H_2O_2 = P_4O_8 - 2(HO_2)$. When this compound is acted on by a second mol. of water, and without having previously undergone the operation of splitting, the resulting product will be a mol. of the tetrabasic pyrophosphate of water with the formula, $P_4O_6 - 4(HO_2)$. With a third mol. the latter gives birth, finally, to the hexabasic watersalt, $P_4O_4 - 6(HO_2)$, which is speedily made to split up into two mol. of the tribasic orthophosphate of water, $P_2O_2 - 3(HO_2)$. It is worthy of remark, that one mol. of orthophosphate and one of metaphosphate of water

are capable of furnishing two mol. of pyrophosphate; and a comparison of their rational formulae will show at a glance that the accompanying molecular changes take place in the following order:—In the first stage the orthophosphate splits up into a mol. of pyrophosphate and a mol. of water, according to the equation $P_4O_4 - 6(HO_2) = P_4O_6 - 4(HO_2) + H_2O_2$, whereupon the co-operating metaphosphate, by combining with the newly formed water molecule—furnishes a second mol. of pyrophosphate, according to the equation, $P_4O_8 - 2(HO_2) + H_2O_2 = P_4O_6 - 4(HO_2)$.

The author then proceeds to contemplate in the

SECOND PART

the action of the chlorides and oxychlorides of phosphorus upon the watersalts of hypophosphorous, phosphorous, and phosphoric acids.

1st Case.—$P_2Cl_3 + 3[(P_2 - H) - 2(HO_2)] = 2[P_2 - 3(HO_2)] + P_4 + 3ClH$. In the first stage of the reaction we have the equation $P_2Cl_3 + [(P_2 - H) - 2(HO_2) = (P_2Cl_2 - HO_2) + [(P_2Cl - H) - HO_2]$, which shows that the mol. Cl and HO_2 have exchanged places with each other; but these transition-products are speedily made to split up, the former into the molecules, $P_2 - ClO_2$ and Cl H, and the latter into the molecules $P_2 - HO_2$ and ClH. In the second stage the newly-formed molecules P_2ClO_2 and $(P_2 - HO_2)$, by ceding their oxygen to the two remaining mol. of hyposulphite, give rise to two mol. of phosphite, one mol. of P_2Cl and one mol. of $P_2 - H$. The sustitutional action of these latter compounds upon each other yields, finally, a mol. of ClH and a mol. of $P_2 - P_2$, which, by the process of self-condensation is speedily converted into a mol. of ordinary phosphorus, P_4.

2nd Case.—$P_2Cl_3 + 4[P_2 - 3(HO_2)] = 3[P_2O_2 - 3(HO_2)] + 3ClH + P_4$. The first stage of the reaction is marked by the exchange of places between the molecules Cl and HO_2, involving the formation of the two transition-products $P_2Cl_2 - HO_2$ and $P_2Cl - 2(HO_2)$. These compounds are soon made to split up into the respective molecules P_2ClO_2 and $P_2O_2 - HO_2$, with simultaneous evolution of one mol. ClH from each. Finally the oxidation of the three remaining mol. of phosphite, at the expense of P_2ClO_2 and $P_2O_2 - HO_2$, gives birth to three mol. of phosphate together with the molecules P_2Cl and $P_2 - H$, which, by reacting on each other in the manner previously explained, will finally engender a mol. of ClH and a mol. of P_4.

3rd Case.—$P_2Cl_3 + 3[P_4O_6 - 4(HO_2)] = 6(P_2O_4 - HO_2) + [P_2 - 3(HO_2)] + 3ClH$. In this reaction the three pyrophosphate of water-molecules resolve themselves, first of all, into six mol. of monobasic metaphosphate, $P_2O_4 - HO_2$ and $3(H_2O_2)$. One of these water-molecules being now brought to bear on the mol. P_2Cl_3, gives rise to the transition-product $P_2Cl_2 - HO_2$, according to the equation $P_2Cl_3 + H_2O_2 = P_2Cl_2 - HO_2 + ClH$, whereupon the second mol. of water, by acting on the mol. $P_2Cl_2 - HO_2$, gives birth to the transition-product $P_2Cl - 2(HO_2)$ plus one mol. of ClH; and this again, with the aid of the third mol. of water, is made to resolve itself into a mol. of phosphite of water = $P_2 - 3(HO_2)$ plus one mol. of ClH.

4th Case.—$P_2Cl_3 + [P_2O_2 - 3(HO_2)] = 3(P_2O_4 - HO_2) + [P_2 - 3(HO_2)]$. In the first stage of the reaction we have the equation $P_2Cl_3 + [P_2O_2 - 3(HO_2)] = (P_2Cl_2 - HO_2) + [P_2ClO_2 - 2(HO_2)]$; in the second stage we have the equation $(P_2Cl_2 - HO_2) + [P_2O_2 - 3(HO_2)] = [P_2Cl - 2(HO_2)] + P_2ClO_2 - 2(HO_2)$; and in the third stage we have the equation $[P_2Cl - 2(HO_2)] + [P_2O_2 - 3(HO_2)] = [P_2 - 3(HO_2)] + [P_2ClO_2 - 2(HO_2)]$. Finally, the three mol., $[P_2ClO_2 - 2(HO_2)]$. resolve themselves into three mol. $(P_2O_4 - HO_2)$, and 3ClH.

5th Case.—$3P_2Cl_5 + [(P_2 - H) - 2(HO_2)] = 2(P_2Cl_3O_2) + 2P_2Cl_3 + 3ClH$. In this reaction we have the following equations:—First equation, $P_2Cl_5 + [(P_2 - H) - 2(HO_2)] = (P_2Cl_4 - HO_2) + [(P_2Cl - H) - HO_2]$; second equation, $P_2Cl_5 + [(P_2Cl - H) - HO_2] = (P_2Cl_4 - HO_2) + (P_2Cl_2 - H)$; and third equation, $[P_2Cl_5 + (P_2Cl_2 - H) = (P_2Cl_4 - H) + P_2Cl_3]$; finally, $2(P_2Cl_2 - HO_2) = 2P_2Cl_3O_2 + 2ClH$, and $(P_2Cl_4 - H) = P_2Cl_3 + ClH$.

6th Case.—$3(P_2Cl_5) + [P_2 - 3(HO_2)] = 3(P_2Cl_3O_2) + P_2Cl_3 + 3ClH$. In this reaction we have the following equations:—First equation, $P_2Cl_5 + [P_2 - 3(HO_2) = (P_2Cl_4 - HO_2)] + [P_2Cl - 2(HO_2)]$; second equation, $P_2Cl_5 + [P_2Cl - 2(HO_2)] = (P_2Cl_4 - HO_2) + (P_2Cl_2 - HO_2)$; third equation, $P_2Cl_5 + (P_2Cl_2 - HO_2) = (P_2Cl_4 - HO_2) + P_2Cl_3$; fourth equation, $3(P_2Cl_4 - HO_2) = 3(P_2Cl_3O_2) + 3ClH$.

7th Case.—$3(P_2Cl_3O_2) + 6[(P_2H) - 2(HO_2)] = 3(P_2O_4 - HO_2) + 2[P_2 - 3(HO_2)] + 2P_4 + 9ClH$. In the first stage we have the equation $3(P_2Cl_3O_2) + 3[(P_2 - H) - 2(HO_2)] = 3(P_2Cl_2O_2 - HO_2) + 3[(P_2Cl - H) - HO_2]$, and in the second stage we have the equation, $(P_2Cl_2O_2 - HO_2) + 3[(P_2Cl - H) - HO_2] = 3[P_2ClO_2 - 2(HO_2)] + 3(P_2Cl_2 - H)$. These two compounds are then speedily made to split up, the former into $3(P_2O_4 - HO_2)$ plus 3ClH, and

the latter into $3(P_2Cl)$ plus 3ClH. In the third stage we have the equation, $P_2Cl + [(P_2 - H) - 2(HO_2)] = (P_2 - HO_2) + [(P_2Cl - H) - HO_2]$, together equal to $2(P_2 - HO_2) + ClH$. The fourth stage is marked by the oxidation of the two remaining hypophosphite of water-molecules, at the expense of the two mol. $(P_2 - HO_2)$, with formation of two mol. of phosphite of water, while $2(P_2 - H)$ remain. These latter are finally made to transpose with the two mol. P_2Cl, with formation of two mol. P_4 and two mol. ClH.

8th Case.—$3(P_2Cl_3O_2) + 2[P_2 - 3(HO_2)] = 3(P_2O_4 - HO_2) - 2(P_2Cl_3) + 3ClH$. In the first stage we have the equation $2(P_2Cl_3O_2) + 2[P_2 - 3(HO_2)] = 2(P_2Cl_2O_2 - HO_2) + 2[P_2Cl - 2(HO_2)]$. In the second stage we have the equation $2(P_2Cl_2O_2 - HO_2) + 2[P_2Cl - 2(HO_2)] = 2[P_2ClO_2 - 2(HO_2)] + 2(P_2Cl_2 - HO_2)$. In the third stage we have the equation, $P_2Cl_3O_2 + (P_2Cl_2 - HO_2) = (P_2Cl_2O_2 - HO_2) + P_2Cl_3$, and $(P_2Cl_2O_2 - HO_2) + (P_2Cl_2 - HO_2) = [P_2ClO_2 - 2(HO_2)] + P_2Cl_3$. The three mol. $[P_2ClO_2 - 2(HO_2)]$ will then finally resolve themselves into three mol. $(P_2O_4 - HO_2)$, and three mol. ClH.

In the preceding pages the author has endeavoured to show, with the aid of a great mass and variety of valuable experimental evidence, not only what is the precise nature of the principal molecular changes which take place in a given reaction, but likewise what is the precise order in which these changes are made to succeed each other. It becomes clear, therefore, that unless these two cardinal points are satisfied, no theory, however ingeniously planned and elaborated, can lay claim to its being a true and trustworthy exponent of chemical phenomena.

XXIII.—*Volumetric Process for the Estimation of Cobalt and Nickel.* By John Clark, Ph.D., F.I.C., F.C.S.

[Read before the Chemical Section, 19th March, 1883.]

This process depends on the fractional precipitation of cobalt and nickel by means of a soluble sulphide of calcium, and is specially intended for the estimation of these metals in presence of manganese.

For this purpose sulphide of calcium is well adapted, as it does not immediately precipitate manganese, and sulphide of manganese is decomposed when boiled with a cobalt or nickel solution.

Preparation of the Sulphide of Calcium Solution.—The sulphide of calcium which I employ for the purpose consists essentially of bisulphide of calcium. It is prepared by boiling equal weights of lime and sulphur for about an hour, and filtering off the insoluble. The reddish yellow liquid thus obtained keeps best in the concentrated state, and can be diluted when required. It is not a pure sulphide of calcium, but it is suitable for the purpose. In estimating cobalt and nickel it is advisable to use a very dilute solution; one in which each measured grain is equal to about ·0025 grain of cobalt will be found very suitable for the purpose.

Standardising the Solution.—To determine the strength of the standard solution I prefer to use a known weight of anhydrous sulphate of cobalt, because it is the most stable salt of cobalt, and can be heated to a tolerably high temperature without decomposition, and I determine the strength of the dilute sulphide of calcium each time it is used. In doing this it is advisable to employ a quantity of the cobalt salt corresponding approximately to the proportion of cobalt and nickel which you expect to have to deal with.

In applying this process in the analysis of any substance, the metals of the H_2S group are removed in the usual way, and after oxidation the iron and alumina may be precipitated with carbonate

of lime or carbonate of baryta. The solution, which should then be as neutral as possible, and may contain the cobalt and nickel, or either, as chlorides or sulphates, is diluted, if necessary, till it does not contain more than $\frac{1}{4}$ grain of cobalt or nickel to the fluid ounce. It is then heated to the boiling point, and the standard sulphide of calcium solution added from a burette to the hot liquid, till a drop taken out on the end of a glass rod and brought in contact with a very weak solution of sulphide of calcium ceases to give a dark colouration.

To obtain correct results in this way there are several points which require attention—1st. The sulphide of calcium used as an indicator should be much weaker than the standard solution. A suitable indicator is obtained by mixing one part of the standard solution with about 10 parts of water. 2nd. The volume of the sulphate of cobalt solution used for standardising the sulphide of calcium should be about the same as that in which the cobalt or nickel is to be estimated, and the indicators should be of the same strength. 3rd. The size of the drops should also be in both cases about the same, as the dark colour disappears in excess of the sulphide of calcium.

The following experiments will give some indication of the results which may be obtained by this process:—

I. 3 grains $CoSO_4$ required 46·5 div. CaS_2 sol. = 1·137 grains of Co or ·02445 grain Co per alkalimeter division.

II. 3 grains $CoSO_4$ + 3 grains sulphate of manganese required 47·75 div. CaS_2 sol. = 1·1674 grains of Co, or 38·91 per cent. Theoretically, 37·9 per cent.

III. A solution containing 1·137 grains of Co and ·471 grain of Ni, or 1·608 of cobalt and nickel, and at the same 5 grains of sulphate of manganese required 67 div. CaS_2 sol. = 1·638 grains of Co and Ni, or 101·85 per cent.

It will readily be understood that a drop of the cobalt or nickel liquid will cease to give any indication with the sulphide of calcium solution before the whole of the cobalt or nickel is precipitated, but for comparative purposes this does not affect the accuracy of the result when the experiments are made under similar conditions. The process may, however, be modified so as to precipitate the whole of the cobalt and nickel, and in unpractised hands the results thus obtained are better, but of course the experiment takes more time. To ascertain the point at which the precipitation of the cobalt and nickel is complete, it is necessary, after the

liquid has ceased to give a dark colour with the sulphide of calcium indicator, to filter off the precipitated sulphides of cobalt and nickel. The clear solution—which will contain only a very small quantity of cobalt and nickel—is then heated to the boiling-point as before, and the standard solution of sulphide of calcium is cautiously added till it ceases to give a black precipitate. Of course, when this modification is adopted, it is necessary to determine the strength of the sulphide of calcium in exactly the same way.

The following results were obtained by this method :—

I. 3 grains $CoSO_4 = 1{\cdot}137$ grains Co required 50 div. CaS_2 solution.

II. 3 grains $CoSO_4$, with an equal quantity of sulphate of manganese, required 56 div. = 1·157 grains of Co, or 38·56 per cent. Theoretically, 37·9 per cent.

III. A solution containing 1·137 grains of cobalt and ·471 grain nickel, with 6 grains of sulphate of manganese, required 77 div. CaS_2 solution = 1·5909 grains cobalt and nickel, or 98·93 per cent. of the total cobalt and nickel present.

In addition to these experiments, I have made a number with earthy cobalt ore, and from the results which I have obtained I am satisfied that the process which I have described is capable of giving very accurate results. The process is not applicable for the estimation of Co or Ni in presence of zinc, as in a neutral or nearly neutral solution the sulphide of zinc is not decomposed by a cobalt salt, so that zinc is precipitated locally and does not redissolve.

XXIV.—*On the Development and Generic Relation of the Corals of the Carboniferous System of Scotland.* By Mr. JAMES THOMSON, F.G.S., Honorary Member of the Royal Ducal Society of Jena; Corresponding Member of the Royal Society of Science of Liège; and President of the Biological Section of the Philosophical Society of Glasgow.

[Read before the Society, 14th March, 1883.]

INTRODUCTION.

FOR a number of years it has been frequently remarked to me that there were not a few of the members of the Society who considered it desirable that I should give a more or less brief description of how and by what means the coralline remains, constituting the subject of my communications to the Society, were formed. That such a request should be expressed gives me no surprise. The number, variety, and near relation of many of the species that have been and are to be described must be more or less puzzling to the uninitiated, when he attempts to form an adequate conception of the relationship that exists between these apparently diverse forms. In attempting to do so, I have abstained from entering into the wide domain of speculation, and, as far as our knowledge goes, I will take a clear comprehensive view of all the known facts, endeavouring to estimate as impartially as I can the biological deductions which the results of my investigations warrant.

The subject I have chosen for my address is one which has more or less engaged the attention of naturalists from the time that Lamark in his *Philosophie Zoologique*, in 1801, published his views. There, for the first time, he announced the doctrine that all species are the resultant of pre-existing life and law. This deduction he arrived at from the difficulty in

distinguishing species and varieties felt by all systematic investigators. He found a constant and persistent transition from the one into the other, and suggested that all of these modifications were alike due to physical conditions, the crossing of existing species, and to use or disuse—or, in other words, to the effect of habit. As might have been expected, such an innovation on pre-existing views was met with a storm of opposition that for a time rendered obnoxious all observers who ventured to express the slightest sympathy with his views. Subsequent investigations, however, surrounded biological thought with a halo of interest. Further, these speculations are of great scientific importance in the elucidation of the natural laws governing organic life. The mobility of organic nature is so plastic that there is now no longer surprise expressed when the naturalist, in the different departments of biological inquiry, ventures to trace the principles of development and co-relation. And if we accept the view that all organic forms are thus more or less plastic in their organization, then there is no reasonable grounds for doubt as to the modification of species, nor that variation has been and is being produced from the altered conditions of the surroundings and the tendency to variation from natural selection, and possibly from other causes not at present known.

In considering the development of the corals of the carboniferous system, it is quite possible that the biologist, in comparing the closely-related forms which are represented in these organic remains, and their embryonic relations and other facts abundantly represented in their distribution throughout the system, might be induced to believe that the presence of forms so closely related to each other has been brought about by slow and progressive stages of development, arising from the tendency in the living organism to become more or less modified, chiefly under the action of surrounding conditions, facilitated by the plasticity and mobility of the tissues of the living animal. It is therefore of the highest importance that we should have as clear a knowledge of the soft tissues as of the sclerodermic skeleton of the animals producing corals. In attempting to do so, I am not insensible of the fact that the evidence we seek is enshrouded in the depth of past time; but, in this, as in all the other palæontological evidence of the life-history of animals living in the past, we at least can only be guided by analogy. We therefore must trace their relationship

by means of animals whose organization we know, and we assume that the creatures that fabricated these ancient organic remains were similarly organized.

It will thus be apparent that the study of the different groups and varieties of the fossil corals of the carboniferous system may be aptly introduced by a brief reference to a few of the details of the soft parts of the animals which fabricate these wonderful and varied remains of organic life. It is the province of the biologist to be exact. It is the first and highest duty of the student to collect accurate data. To do so with even an approximation to an exhaustive treatise would require a volume of considerable dimensions. I will therefore try shortly to describe the relation between the soft parts of the animal and the sclerodermic skeleton. And while we can only judge of these remains from analogy, and be guided by the information so admirably presented in the works of Dana, Darwin, Edwards and Haime, Köninck, Duncan, Duthiers, Moseley, and others, and from an implicit confidence in the universality of the laws of nature, we are led to believe that, even to approximately know these remains, we must compare the products of the present period with the remains found imbedded in the wreckage of the past. In order to present that relationship clearly, I shall, in the *first* place, briefly refer to the organization of those animals which we believe to be their nearest allies. In the *second* place I shall describe the different modes of reproduction. In the *third* place I shall trace the relationship between the soft parts of the animal's body and the sclerodermic skeleton or coral. *Fourthly*, I shall describe the different parts of a corallum. And *fifthly*, I shall trace the generic relations of the coralline remains of the carboniferous system. If I succeed, we will find, instead of the desultory and unsatisfactory method of describing a genus here and a species there, we will have a connected whole—we will have a rational purpose in our research into the structure and relationship of the different genera and species of this widely-distributed group of organic remains. Following out this method, we discover that, in each successive stage of our inquiry, there is exhibited a progressive development; and if I succeed in tracing the connecting stages of development, I venture to think the overwhelming conviction will be that modification is stamped upon each form, and in this way only can we account for the organic forms as a whole.

Before entering upon a detailed reference to both the generic

and the specific relations of each group, allow me to state that in no instance can we draw a hard and fast line between either genera or species. Many of the forms which, if examined by themselves, would be accepted by any competent palæontologist as being specifically distinct, but which are found in a large variety of the same genus to possess characters which are so closely similar to other forms that they are linked to them by intermediate gradations of so minute a character as to make it difficult to define their place and position in any work of systematic classification. While I am aware that in many of these closely-allied forms there is abundance of duplicatory evidence showing that they have retained their distinctive characters over wide areas, practically we can only regard such closely-allied forms as mere varieties, and to select those forms that are distinct in their character and pronounced in their relationships as central types, around which varieties and species diverge in both directions. Hence, in determining whether a form should be ranked as a species or a variety, reference must be made to a large series of selected specimens. External aspects may, and do, indicate generic relations, but cannot be accepted as evidence to warrant specific distinction. Hence, such minute transitional differences are apt to puzzle and confuse the systematists; yet such are of high importance to the biologist, whose object is to know the why and the wherefore, and who regards species which are more or less distinct and permanent as connecting links, and those forms that are less strongly marked as sub-species, which, with further differentiation and development, would become distinct in their specific characters. At best, we can only regard the term species as extremely mobile, and only used for convenience in grouping those forms which are nearly related, and those forms whose minute differences of structure only ranked as varieties, but which to the biologist are of essential importance in enabling him to trace the development and transitional differences to a united whole.

Milne-Edwards and Jules Haime, in their admirable memoir in the *Transactions* of the Palæontographical Society, 1852, only described forty-three species from the carboniferous rocks of Britain. Since then that list has been considerably added to by de Köninck, Duncan, and others, yet comparatively little has been done in this department of palæontology to what might and ought to have been done. It may be adduced that our imperfect knowledge of the geological record has debarred more extensive investigations

The zone in which the great majority of coralline remains are found is limited to a small portion of the lower members of the carboniferous limestone, and it is only here and there in widely-separated localities that this limestone is exposed; and, even in those localities which have yielded the greatest variety of forms, the sections which have been unearthed are merely a few scratched fragments of that great system, and it is only by frequently visiting those localities, and watching the exposures made for economic purposes in the coralline zone, that we can hope to acquire these remains as they are from time to time exhumed. Thus, to acquire a collection of even moderate dimensions, years must be spent in constantly watching and collecting.

There is, however, another and a very potent obstacle to the systematic study of this department of palæontology—*i.e.*, when the specimens are procured, each must be sectioned transversely, and, in order to know the structural characters throughout the corallum, a portion of each genus must be cut longitudinally and carefully polished. It is also essentially necessary to know if the structural details, upon which generic distinctions are founded, are continuous from the inferior to the superior extremity of the corallum. Some of the forms must be sectioned at different parts of the corallum; in this way only can we hope to arrive at a knowledge of this group of organic remains* — to accomplish which involves a large expenditure of both time and money. In the present condition of our public museums the student cannot hope for material assistance. Even in our great National Museum the number of specimens of both genera and species is absolutely nothing compared with the number of forms which could be procured throughout the three kingdoms.

*As my work has been for a number of years misrepresented, and by those whose position ought to respect honest work, and who have stated that I created species from sections made from different parts of the same corallum, I may be permitted to remark that in one of my earliest reports read to the British Association, and in several of my subsequent papers, I placed in a most conspicuous position, *i.e.*, the following remarks, "It is only from sectioning the corallum at different stages that we can, with any degree of confidence, define either generic or specific relations." With some, and more especially those who have never seen how my investigations have been conducted, this has been of no avail. Great is the influence of such misrepresentations, but recent experience shows that this influence does not long endure, and more especially with those whose position in the scientific world renders their opinion worthy of respect.

I.—THE SOFT TISSUE OF THE ANIMALS FORMING CORALS.

When a simple or compound corallum is in its native element, viz., sea-water, its superior extremity, or calice, is enclosed in and covered by soft tissue, which, when filled with water, is largely distended. Around the periphery there are a circlet of tentacles, which may either be a single circlet (Pl. II., Fig. 1), or there may be a double circlet (Pl. II., Fig. 2). When they are double, the larger are termed the primary, and the smaller are termed the secondary, tentacles. The tentacles vary in length and stoutness in different species, and at their base are continuous with the disc, and opening into the upper part of the mesenteric cavity (Pl. I., Fig. 1B).

The visceral cavity is divided by radiating partitions into a number of chambers or mesenteric folds, separated by intermesenteric spaces (Pl. I., Fig. 1B), which freely opens into the centre of the main cavity of the body, and the septa correspond in their length, number, and stoutness with the proportions of these mesenteries, which give rise to the interseptal dissepiments.

The mesenteric cavity is bounded below by the tissues covering the base of the pylorus (Pl. I., Fig. 1C), the wall, and the dissepiments which form the floor of the interseptal spaces (Pl. 1, Fig. 1D). It will thus be apparent that there is a close relation between the tentacles and the septa—indeed the septa are in direct proportion to their number, and are deposited at their base.

In the interior of the tentacles there is a system of retractile muscles which converge inwards and downwards (Pl. I., Fig. 1E).

The mouth is situated in the centre of the disc, and leads into a distinct digestive sac, which is suspended in the main cavity or stomach (Pl. I., Fig. 1H), and is separated from the visceral cavity, which is bounded below by a slight constriction—the "pylorus" (Pl. I., Fig. 1F).

In many of the forms there are a series of radiating folds or lines extending from the lips of the mouth outwards to the inner ends of the primary tentacles, which at their base extend inwards to the columella (when present) at the base of the pylorus (Pl. I., Fig. 1G). These folds correspond with the number and arrangement of the lamellæ of the central area of the corallum. The presence of a columella and lamellæ infers that the visceral cavity will be proportionally circumscribed, and that in those

forms in which these are absent there is a corresponding increase in the size of the visceral cavity.

The outer covering or wall, like the other soft tissue of the animal, is formed of two layers, and the dense epitheca is a counterpart, and secreted by the soft tissue from the base of the corallum, and is called "fort secretion" by Dana.

The base of the internal membrane lines the interseptal loculi, the structure in the columellarian area (when present), and secretes inferiorly the sclerenchymatous skeleton of the corallum, which is therefore a counterpart of the internal organization of the soft tissue of the animal's body.

In addition to those here referred to, there is a group which, from the structural details of the corallum, warrants us in assuming that the polype had a double circlet of tentacles. It has been already stated that the wall bounds the corallum, and is an expression of the outer covering or wall of the animal's body, and forms the periphery of the calice at the superior extremity. In this group, however, which forms the exception, there is a double calice or cup, which is also bounded by a distinct wall, and around the inner margin of this inner wall or periphery there is a system of distinct minute septa, which converge inwards from the wall to the centre of the calicular cavity, and the loculi are occupied by minute interseptal dissepiments similarly arranged to those of the outer system of septa. These characters, so widely different from all the known groups of *Cyathophyllidæ*, have induced me to assign to them a distinct and separate family, under the designation of *Diplocyathophyllidæ*. Pl. I., Fig. 2, is a restoration of what I conceive the animal was like, and Pl. XIV., Figs. 3 and 5, represent a *facsimile* of the double calice of a corallum, and Pl. XIV., Fig. 1, the structural details upon which I base my deductions.

In watching the phases observable in the earlier stages of development, it will be observed that there are a series of changes through which the ova pass. After immersion, they are first observed as a cluster of ovular bodies. In a number of cases the central portion of the mass dissolves, and the outer portion resolves itself into the blastoderm, which, when further developed, is observed to consist of two layers. Thus the organization of the animal consists of an outer layer, termed the ectoderm, and an inner, termed the endoderm. And these surround a simple structureless cavity, which constitutes the entirety of these simple creatures. Such is a cursory idea of the biological structure of those forms of

the hydrozoa that we have reason to believe are analagous to the animals that formed the fossil remains of that group in the carboniferous system* (Pl. III., Figs. 3, 4, 5, 6). And although their history is obscured in the depths of past ages, yet, from a careful comparison of these remains, we discover the great truth that both those of the present and the past are built up in the same fundamental type.

II. REPRODUCTION AND MULTIPLICATION.

(1) *Ovular Reproduction.*—Although the data by which we can be guided regarding the earlier stages in the development of the polyp is meagre, it is, however, asserted by some of our ablest authors that the ova are developed in the "mesenteric folds," which in the earlier stages consist of groups of minute spherical bodies or cells of protoplasm. In tracing the successive phases it has been observed that there are four stages through which they pass before they begin to secrete the calcareous matter of which the corallum is composed.

It has been already stated that these ova are first seen in the mesenteric folds in groups of minute spherical bodies (Pl. I., Fig. 1H). In the second stage they are separated from the parent and escape through the free ends of the mesenteries (Pl. I., Fig. 1D) into the visceral cavity (Pl. I., Fig. 1H), and are expelled through the stomach and mouth (Pl. I., Fig. 2), and each has an independent existence (Pl. I., Fig. 3). In the third stage they become somewhat elongated, and float about by means of minute cilia until they find a suitable place to become attached (Pl. I., Figs. 4 and 10. In the fourth stage a depression or infolding of the superior extremity takes place (Pl. I., Figs. 6, 9, 11, and 12), and becomes more or less concave—thus the inverted wall is called the endoderm and the outer wall the ectoderm. Now, however, a marked difference is observable. In the earlier stages these ovular bodies present a simple aspect, but development proceeds, and the ovum assumes a definite form. It then begins to secrete the sclerodermic skeleton, and each group differentiates after its own kind, and the secreted parts become, in form, structure, and appearance, somewhat similar to its prototype, or may become

*After Lacaze Duthiers' Hist. de Developement des polypes et de leur polypier.

more or less affected by the altered conditions of the surroundings; and we have abundant evidence to believe that changes in the surrounding conditions have a tendency to increase variability.

It is generally understood that the first appearance of the stomach is brought about by an inversion of the oral aperture of the ovum. Professor Lucaze Duthiers, in his admirable memoir ("Hist. Nat. de Corail"), Pl. I., Figs. 5-10 (after Duthiers), shows the successive stages of development through which the ova passes. In the first stage they are gibbose in the superior extremity; in Fig. 9 there is represented a slight depression; in Fig. 5 a further inversion is observable; and in Figs. 6, 11, and 12, there is represented not only a deeper infolding, but also a series of lateral folds or puckering, the upward growth of which gives rise to the tentacular crown, and suggests the first indication of the septal system surrounding the stomach sac as separate and independent structures formed between the outer walls and the inverted mouth margin; and, as Duthiers I believe correctly suggests, in the more advanced stage the septa are developed at the base of these radiating folds (Pl. I., Fig. 7). This view is supported by the structural details found in the great majority of the fossil corals of the carboniferous system that has been examined by me. At the base the sclerenchyma is first observed as a homogeneous covering, in which with increased growth the secreted matter becomes more dense. Then a series of depressions or separiæ are developed, which with increased development presents a series of stout septa, which with further development becomes more and more delicate. Then the lamellæ of the septa is observed in the form of longitudinal cells. As development progresses the septa become less stout and the lamellar aspect more distinct, and a series of minute partitions (or trabiculæ) between the elongated cells resolve themselves into the minute delicate interlamellar plates (trabiculæ) (Pl. XIV., Figs. 3A and 8A), first recorded in my paper on the genus *Centraphyllum* in the *Transactions* of this Society, Vol. XII., p. 225, and which I believe to be an expression of the retractile muscles of the tentacles.

(2) *Gemmation.*—By gemmation is meant the development of a corallite directly from the tissue of the parent, which arises in the interseptal loculi. In some forms it is calicular, and in others it is latro-calicular.

(*a*) *Calicular* gemmation takes place in the interseptal loculi, and in those forms in which the growth of the young is fatal to the

life of the parent (Pl. II., Fig. 3, and Pl. VII., Fig. 10). Gemmation takes place near the inner margin of the interseptal loculi, and may be termed true calicular gemmation.

(*b*) *Latro-calicular* gemmation takes place in the interseptal spaces, and near the periphery of the corallum, and in the earliest stage is indicated by the widening and enlargement of the interseptal space. Then a secretion of granular sclerenchyma more or less cylindrical is observed, which with increased development becomes more dense. In a more advanced stage the sclerenchyma becomes divided into elongated plates. These divided segments are the base of the septa, which now presents a more or less definite form. The young corallite then emerges through the vesicular tissue that surrounds the septal system. The wall is then seen to be slightly distended and ultimately ruptured; then the young corallite emerges and grows side by side with the parent, which produces a common form of compound corallum (Pl. II., Figs. 5 and 6, Pl. IX., Figs. 1, 1E, and 1F).

(3) *Fissiparous Growth.*—This mode of reproduction is well exemplified in the genus *Alveolites*, Lamark (Pl. IV., Figs. 3, 3A, and 3B), and also in the genus *Diphyphyllum*, Lonsd. (Pl. VIII., Figs. 1 and 1A). In the former genus teeth-like projections are seen as minute points, and can be traced extending across the calice, and becoming attached to the opposite wall, producing complete fission, and the young grows side by side with the parent, and forms dense compound communities (Pl. IV., Figs. 3, 3A, and 3B). In *Diphyphyllum*, and other allied genera, the calice is bisected through the centre of the corallum, and the growth of opposite septa is observed, which ultimately merges into two independent corallites (Pl. II., Fig. 4; Pl. IX., Figs. 5 and 8).

The above is a brief summary of the different modes of development in the corals of the carboniferous system. For a more detailed description I have to refer to the elaborate descriptions given in Dr. Duncan's valuable Memoir, in his introduction to *The Corals of the Tertiary Formation.* (Palæontographical Society Transactions, 1866.)

III.—THE RELATION BETWEEN THE SOFT PARTS OF THE ANIMAL'S BODY AND THE HARD SKELETON OF THE CORALLUM.

The hard parts of the corallum are inclosed in and secreted by the soft tissues. After the ova has passed through the earlier stages of development, and when the superior extremity has

become deeply enfolded, and, being pressed inside of the inferior portion of the ovum, necessarily gives rise to the enfolded portion being more or less puckered along the lateral wall, giving rise to the development of the lateral divisions or septa of the Polyp, an extension and upward growth of which ultimately becomes the tentacles that surround the superior extremity of the Polyp. Now, the different parts of the animal's body becomes filled with sea water. Now, these creatures, like all other animals, cannot exist unless they receive a constant supply of oxygen, and that oxygen can only be extracted from the water that fills its body. The separation of the oxygen from the water necessarily leaves the other ingredients that are held in suspension in the water. Now, by a beautiful arrangement in nature, these ingredients are thrown down to the lower part of the animal's body, and, being still in a liquid mass, and the animal tissue of the Polyp's body being porous, the calcareous substance of the water is segregated through the pores of the animal tissue. This invisible process going on from time to time, as each volume of oxygen is separated from its neighbouring mineral constituents, which, being secreted through the porous tissue of the animal, and as each successive cell and layer is secreted and built upwards, the animal, in proportion with the increased growth, rises higher, and in turn secretes another floor, extending across and filling in the whole width of the cavity of the corallum, and thus forms a counterpart of each portion of the internal organization of the Polyp's body. It will thus be manifest that such a delicate process, and of such exquisite minuteness, going on from day to day, must produce results of extreme variety.

It would be a matter of deep interest to ascertain what proportion of segregated matter is secreted in a given time. If such could be accomplished, we would thus ascertain the life history of each form.

From what has been stated it will be apparent that the structural details of a corallum are simply a counterpart of the internal organization of the Polyp's body. The outer skin secretes the epithecal layer. The septa are secreted at the base of the tentacles. The interlamellar striæ of the septa are an expression of the retractile muscular striæ that are situated inside of each tentacle. The interseptal dissepiments are secreted at the base of the internal membrane that lines the interseptal loculi. The lamellæ in the central area are secreted from the centre of the

base of the pylorus, to the inner margin of the primary septa, and the interlamellar dissepiments are an expression of the interlamellar membrane. The columella in the centre of the pylorus possibly is the result of a central depression. The tabulæ in the tabulatæ is an expression of the more simple digestive organs of the tabulate forms of the hydrozoa, which in some forms extends across the corallum from wall to wall, whilst some of the species of the genus *Aulopora* there is a total absence of tabula, while in others the tabula is developed near the base, *Aulopora campanulata* (Pl. III., Fig. 4), in which there is in some of the corallites two, and in others three tabulæ, and which induces me to believe that in this genus we have an intermediate or connecting link between the *Auloporidæ* and the *Tabulatæ*. The tabulæ, however, are not constant. In examining a number of polished specimens in my cabinet, I find the proportion of tabula developed in one specimen, which contains fully two hundred corallites, to be as one to twenty, while in another specimen, from another part of the country, the proportion is as one to four of the non-tabulate forms—indicating that the modifications in these have been produced from an innate tendency to variation in the tissue of the living animal.

(1) *The different parts of a Corallum.*—The upper extremity of a corallum is called the calice (Pl. XIV., Fig. 3). Its outline is bounded by the wall, and its depth is determined by the arrangement of the septa, the structural details of the central area, or floor of the fossa. The periphery of the calice is called its margin, and its floor is formed by the septa, the dissepiments of the interloculi, the crown of the columellarian area, and in the tabulata, by the tabulæ. The calices are extremely varied in depth and outline. Some are circular, others are oval or elliptical, and nipped in the centre, angular, whilst others are rhomboidal, pentagonal, hexagonal, and polygonal.

The calice may be wide and round near the periphery or everted, or it may be thin and inverted. The calice may be deep, shallow, or widely open. Some calices are deformed from external causes; indeed, their form and depth are extremely varied, and they vary both in size and form in the different stages of growth of the same corallum.

(2) *Wall.*—The wall bounds the structural details of the corallum, and, in the great majority of the carboniferous corals, is most important.

The upper extremity of the wall is prominent when the septa are not everted. Its outer surface is variously marked. In some forms there are encircling lines, more or less wrinkled or cranulated, and constrictions, or annulations of growth. The base of the wall is sometimes attached to rocks or other foreign bodies, in which case the base is either broad and concave, which is not infrequent in the tabulate forms (Pl. IV., Fig. 7), or it may be deformed and assume the form of the object it is attached to. In some instances I have found them attached to the spines of Producta (Pl. VI., Fig. 24A), in which case the wall folds round and clasps the body they are attached to. The wall is always more stoutly developed around the base of the simple and conical forms. In some cases the walls are fused together, arising from lateral pressure and fissiparous growth, in compound forms.

In a series of many of the simple forms the mode of growth is indicated. The young are more or less erect, with a delicate pointed peduncle which would seem to have been attached to foreign bodies in the earlier stages of growth. With increased growth, the support not being sufficient, it falls over on its broadside; and the tendency to grow upwards, and to keep the calice above the mud, produces the curved aspect so frequently met with in the simple forms, and more especially when they are found embedded in shale or deposits that have been deposited in shallow water, in which case they are more or less abraded, and usually on the concave or dorsal side of the corallum—indicating that their bathmetical range was restricted to shore and shallow water, and more or less affected by tidal conditions.

(3) *Septa.*—The septa are bilamellar, and extend from the epitheca or wall inwards towards the centre of the corallum. In some forms the septa converge into the centre (Pl. VII., Fig. 2), whilst in others they are intersepted by the structural details of the columellarian area (Pl. XIV., Fig. 11). Those first developed are always the longest, and are termed the primary. The secondary septa are usually small, and in some cases are hardly recognizable in the zone of dense vesicular tissue they intersect.

There are interseptal spaces between both the primary and the secondary septa, and more or less occupied by interseptal dissepiments (Pl. III., Fig. 26c). The carboniferous corals belong generally to forms in which the septa are multiples of four. This, however, is not free from exception; there are forms in which the quaternary arrangement is not apparent.

The number of septa differ according to the age and development of the corallum, and, therefore, cannot be relied upon alone for specific diagnoses.

In some forms the septa are rudimentary, and are represented by minute spines (Pl. V., Fig. 2), in others minute granules (Pl. V., Fig. 1). In some they are stout, whilst in others they are delicate, and the laminæ are hardly recognisable. In all cases the septa in the earlier stages of growth are considerably stouter, and the bilamellar arrangement is early developed.

(4) *Columella.*—The columella is not always present. In, however, a number of genera it is conspicuous in the calice, and forms an important element for diagnostic purposes (Pl. III., Fig. 26c). The arrangement of the structure in the columellarian area is very varied; in some genera it is in the form of a central road, and is developed in combination with the first formed septa, and is termed essential. The styliform columella is represented in the genus *Cyathaxonia* (Pl. X., Figs. 24 to 29). In other forms the central area is composed of lamellæ, which converge inwards from the inner ends of the primary septa to the centre of the central area, and may be termed lamellar (Pl. XIII., Fig. 1). In others the lamellæ converge inwards from the inner ends of the primary septa, and unite into groups, and may be termed fasciculate (Pl. XIV., Fig. 1).

The superior extremity of the columellarian area is extremely varied. In some forms it is spiniform; in others stellaform; in others it is conical; in others dome-shaped; in others helmet-shaped; in others slightly raised at the margin, and more or less depressed in the centre; whilst in other genera it assumes the form of a double cup. It will thus be apparent that the central area of the corallum is of great importance for diagnostic purposes. Indeed, I venture to say that it is in the central area alone we can hope to define accurately either genera or species.

(5) *Costa.*—The costa is so seldom met with in the corals belonging to the carboniferous system, that it is only necessary to state that the costa is regarded as a prolongation of the septa outwards through the epitheca (Pl. IV., Fig. 10).

(6) *Endotheca.*—The structural details that unite the septa (Pl. III., Fig. 25c) and the lamellæ (Pl. III., Fig. 26g) closes in, and forms the floor of the calicular fossi, constitute the endothecal sclerenchyma, and designated by M. Edwards and J. Haime dissepiments. In the tabulatæ the floor of the fossa is closed in

by plates or tabulæ, which are more or less transverse (Pl. V., Fig. 6A).

The dissepiments are greatly developed in some genera, and rectangular in some forms (Pl. XIV., Figs. 1 to 10), while in others they are more or less angular (Pl. XIV., Figs. 11 to 16). In other forms they are delicate and form a dense zone of vesicular tissue around the periphery of the corallum (Pl. XI., Figs. 1, 9, and 12), which in a longitudinal section are convex—convexity upwards and inwards—and arranged in oblique rows (Pl. XI., Figs. 1A, 2A, 3A).

In the tabulata the endotheca consists of horizontal plates or tabulæ, which close in and form the floor of the fossa. Their extent varies in proportion to the development and character of the vesicular tissue in the peripheral region. In some forms the tabulæ extend from wall to wall, and thus occupying the whole width of the corallum (Pl. V., Fig. 1A). In others the tabulæ varies in proportion to the length—the septa extend inwards from the periphery, until in some forms they are all but obsolete (Pl. V., Fig. 18A).

They may be sparse and rectangular (Pl. V., Fig. 6A); or they may be more or less angular (Pl. V., Figs. 1A and 15A; or they may be convex whilst others are concave—indeed, every variety may be found in this group of coralline remains. A few of these are represented in Pl. V., Figs. 1A to 16A).

Professor L. Agassiz, in his contribution to the Nat. Hist. of the N. S., Vol. III., Page 121, "places Millepora and other allied genera in the tabulatæ, and the Rugose Corals are genuine hydroids allied to hydractiniæ. The principal distinctions for separating these sections from the true Polyps are as follows :—The quadripartite structure of the Rugosa is an Acalphian character, and that the radiating partitions of the Rugosa are limited to successive horizontal floors, which are continuous from wall to wall across the total width of the calicular cavity of the coral, and that no coral known to be the skeleton frame of a Polyp has such a structure. On the contrary, in polypariæ the radiating portions of the individual calices occupied by distinct animals extends uninterruptedly from the inferior to the superior extremity of the corallum, and if there exists horizontal floors, these stretch only across the intervals between the radiating partitions or septa."

Professor Dana, in his work on Corals and Coral Islands, expresses a similar opinion, but gives no reasons for his belief.

Professor Verrill, Ann. and Mag. Nat. Hist., 1872, "On the Affinities of the Palæozoic Tabulate Corals with existing Species," combats the deductions of Professor Agassiz that the whole of the tabulata belong to the hydroid Polyps. That such a classificatory position is only applicable to the Millepores. That the other forms of tabulata ought to be grouped with the true Polyps.

L. F. de Pourtalès' Illustrated Catalogue of the Museum of Comparative Zoology at Harvard College—Deep-sea Corals, No. IV. The Rugosa he places at the end of the true corals at page 49, and from the examination of the genus *Lophophyllum proliferum* (M. Edwards and Haime) came to the conclusion that the tetrameral arrangement of the septa for the Rugosa is only apparent, their being originally six primary septa. He, having cut the coral transversely at different parts of the corallum, and at the base or the youngest stage, found six primary septa and six interseptal chambers.

Subsequent investigations by Professor Moseley on the structural details of Millepora from Tahiti, has shown that it is a true Hydrozoon, allied to Hydractinia, as Agassiz maintained, and need not be further referred to.

The deduction arrived at by the eminent authors may be briefly summarized as follows:—Professor Agassiz places the tabulate corals as genuine Hydroid allied to the Hydractinia; that the extinct Rugosa probably belongs to the same class. The reasons assigned are—

First—The quadripartite structure of the Rugosa is an Acalphian character.

Second—The radiating partitions or septa are limited to successive horizontal floors which closes in the calicular cavity from wall to wall.

Third—That no coral known to be the solid frame of a Polyp has such a structure—on the contrary, in Polypariæ the radiating partitions, occupied by distinct animals, extend uninterruptedly from top to bottom of the corallum.

Fourth—And if there exist horizontal floors, they stretch only across the intervals between the radiating partitions.

L. F. de Pourtalès regards the tetrameral arrangement of the septa as being apparent, and asserts that the hexameral arrangement of the septa is found in *Lophophyllum proliferum.*

As regards the corals of the carboniferous system, as formerly stated, much yet remains to be done before we can assert with any degree of certainty their classificatory value; believing that other forms will yet be discovered that will unite more closely groups that at present seem to be anomalies. With our present knowledge—which is founded upon the examination of about fourteen thousand sectioned forms—I may be permitted to place on record what seems to me to be an approximate value of the deductions of these eminent authors, and to append a diagnostic arrangement of the groups in my cabinet, and to arrange them in what seems to me to be their classificatory position.

If the structural characters referred to by Professor Agassiz could be traced as extending throughout the series of the Rugosa, there could be no hesitation in accepting his opinions regarding their place and position as belonging to the Hydrozoa. Many of the simpler forms exhibit the characters referred to by him, *i.e.*, the tabulæ extends from wall to wall. This is always the case in those genera in which the septa are either awanting, or in which there is only one system of septa present. There are, however, developed in the genus *Calophyllum* a system of secondary septa, in which the tabulæ are irregular in their form, and near their outer margins there are irregularly disposed a series of convex plates, which at their inner ends rest upon the tabulæ, and extend outwards to the wall of the corallum. (Pl. V., Figs. 10A, 11A, 12A, and 14A.) In those forms in which the primary septa are more developed, there is a corresponding increase in their number (Pl. V., Fig. 17A), and the tabulæ are more or less intersepted by a zone of loose vesicular tissue, which in the transverse section are seen to be the primary interseptal dissepiments. (Pl. V., Figs. 10, 11, 12, 14, and 17.) It will thus be seen that, in those forms in which the secondary septa are more or less developed, the tabulæ are more or less intersepted by the vesicular tissue that is developed in the interseptal spaces; indeed, in proportion with the increased length of the septa, and the greater development of the interseptal dissepiments there is a proportionate diminution in the width of the tabulæ in the central area, which may be traced in the most minute gradations throughout the genus *Calophyllum* and passing into the genus *Campophyllum*, until in *Cyathophyllum regium*, in which the tabulæ only occupies the centre of the central area.

In the great majority of the tabulate forms the septa extends

inwards, and rest upon the superior face of the tabulæ, and have thus one of the characters upon which Prof. Agassiz based his opinions, *i.e.*, that the Rugosa belong to the Hydrozoa. This character, however, is only observable in those forms in which the tabulæ occupy a large proportion of the total width of the corallum; and in which the septa are restricted to the upper chamber of the corallum. There is, however, a number of forms whose generic relations are based upon the presence of a columellarian rod, extending from the base of the corallum to the crown of the calicular cavity, and which may be said to form an intermediate group, which merge on the one hand, into a group, which are developed either by fission, or by gemmation, in which case the young grows side by side with the parent corallite, and therefore exhibits the characters assigned to the Zoanthida Rugosa. And on the other hand, there are forms in which may be traced the different modifications from the simple columellarian rod, differentiating in varied directions, and passing from the simple rod into forms in which the tabulæ are all but superseded by vesicular tissue (Pl. XI., Figs. 6, 5, 2, 9, 12, and 15), and which merge into others, in which the lamellæ of the columellarian area is foreshadowed, and extending from the columella outwards to the inner ends of the primary septa (Pl. XI., Fig. 14), and thus form an intermediate group between the tabulata and another large and varied series, in which the septa and the lamellæ in the central area extends from the inferior to the superior extremity of the corallum (Pl. XIII., Fig. 8A), in all of which there is a more or less dense vesicular tissue developed between both the lamellæ and the septa, characters which, based upon the opinion of the eminent author, will exclude them from being classed with other Hydrozoa.

In regard to the apparent tetrameral septa in the Rugosa, and the hexameral arrangement of the septa, referred to by L. F. de Pourtalès, as occurring in the genus *Lophophyllum*, I must express a decidedly adverse opinion to that eminent observer. I have examined a large series of specimens of that genus, cut transversely at different heights of the corallum, and in no instance have found the primary septa arranged as indicated by him. In sections made a line from the base I found four primary and four secondary septa, and in all the sections made at different stages the quadrapartite arrangement of the septa is alone found. His objections, therefore, must be put aside as untenable.

If I may be permitted to assign a classificatory position to those in which the lamellæ and the septa extends from the base to the upper extremity of the corallum, I believe their proper position is to group them as belonging to the Actinozoa. I have, therefore, appended a diagnostic table in which I have provisionally grouped them according to their structural affinities. As just stated, this must be regarded as provisional, believing that intermediate forms will be discovered which will unite them even more closely, and illustrate that development has been progressive, and that each group has differentiated from either inherent causes in the animal or modification from the altered conditions of the surroundings.

IV.—Generic Relations.

In tracing the generic relations of the different groups of coralline remains of the carboniferous system, I do so with a full conviction of the difficulties that everywhere present themselves. I hope to point out clearly that the innate tendency to variation is characteristic of every group. Indeed, so much so is this apparent that no rigid definition of what constitutes a genus can be adopted, and that all that we can do, with our present knowledge, at best must be regarded as provisional. Imperfect though our investigations are, yet the facts revealed indicate that other and important structural details will be discovered, which will demonstrate that during the long period of time when the matrix was being deposited in which these organic remains are found, changes in the physiological conditions of the animals, induced not only by the innate tendency to variation, but also from the altered conditions of the surroundings, has more or less produced modifications; and that, in order that we may know their place and position, we can only be guided by reference to the facts as revealed in the structural details and disposition of their parts, and by this means trace the connecting links that unite not only the different parts into an harmonious whole, but also to bind and connect the different genera, and, if possible, unite the tangled thread that binds the simpler forms through the different stages of development, until we reach the most complex organised species, and thus bridge the different groups, and trace their relations from the simple and structureless *Aulopora* (Goldfuss) through the series until we unite and trace their development, and hope to be able to demonstrate that their passage

from the simple forms to the most complex groups is almost by imperceptible gradations.

In considering the different groups and their classificatory value, I have, as far as possible, followed the classification of M. Edwards and J. Haime. There are, however, exceptions. I have separated their genus *Aulophyllum* from the *Cyathophyllidæ*, and grouped it and the genus *Cyclophyllum* (Duncan and Thomson) into a distinct family, viz., *Diplocyathophyllidæ*. Although in this group, as in all the others found in the carboniferous system, there are intermediate forms which unite and link together, not only families and genera, but also species; but conceives that the true definition of a family should rest upon the different patterns of forms induced by distinct embryological details in the morphology of the animals that fabricated and exhibited in the structural details of the corallum, and their generic relations upon their structural details, and their specific distinction upon the relative parts.

In this I have alone been guided by the data presented from a careful examination of an extensive series, consisting of many thousands of sectioned specimens. It is quite possible that my deductions may be objected to, arising from preconceived views; but I venture to assert, if there are those who hold an adverse opinion, if they conscientiously examine the structural characters of these and allied groups they will soon perceive how distinct and natural their classificatory position is; and will soon find how the forms of the group expresses the characters of a natural and distinct family; and that in each genus there are central types in which there are structural details distinct and easily separable from their nearest allies, and how marked and distinct the relative proportion of the parts render their separation and specific distinction of classificatory value. If, however, future investigations should reveal data that will warrant a rearrangement of families, genera, and species, I hope the results of my investigations, if not a decided gain to science, will at least help others to define with greater precision the families herein referred to, and partially characterized. I am satisfied that the systematist, with more favourable opportunities than I can claim, at some future time will find it necessary to rearrange, and possibly a further subdivision of several families, and in all likelihood the reunion of others.

I propose briefly to describe the generic character of each genus, and where it is practicable, to select central types, and to examine wherein those generic central forms are found to merge into their

nearest allies. In doing so, I am well aware of the difficulties that surround the investigation of this wonderful and varied group of organic remains, and hope, by means of the extensive series of plates which the Council of the Society have authorized me to illustrate my address with, to be able to show wherein the structural peculiarities support the view that development has been brought about by a slow and long-continued process of evolution.

DIAGNOSTIC CLASSIFICATION.

HYDROZOA.

- Gemmation by buds, the young corallite is a prolongation of the parent, and form compound communities.
  - without tabula or indicated. septa none. → Aulopora.
  - tabula rudimentary. septa indicated. → Cladochonus.
- The young are developed from ova, and are simple and free.
  - without tabula. septa indicated. → Pyrgia.
- Developed from the ova, and are simple and free.
  - septa more or less developed. tabula at the base of the corallum. → Protocyathophyllum.
- Gemmation either by buds or by fission, and in compound communities.
  - with mural pores. tabula well developed. → Alveolites. Michelinia.
  - without mural pores. → Syringopora.
- Gemmation either by buds or intermural, parasitic, and in compound communities.
  - with mural pores. tabula sparse. → Favosites.
- Gemmation is by buds, or intermural, and the principle corallites, are surrounded by minute vesicular cells.
  - with mural pores. tabula well developed. → Fistulipora. Monticulapora.
  - tabula doubtful. → Palæces. Chætetes. Diastopora.
- Developed by ova, simple and free.
  - tabula present. septa one cyclum, rudimentary, or wanting. → Amplexus.
- Developed from ova, simple and free.
  - with tabula. septa, primary well developed, secondary rudimentary. → Calophyllum Zaphrentis. Cyathopsis.

- Developed from ova, simple and free.
  - with tabula. septa, with primary and secondary. → Campophyllum.

ZOANTHARIA RUGOSA.

- Gemmation by buds. The young remain attached, and form compound communities.
  - with tabula. septa, with primary and secondary. → Diphyphyllum. Cyathophyllum.
  - with tabula. septa, primary present. → Thysanophyllum. Phillipsastrea.
  - tabula divided in two by a columellarian rod. septa of two orders. → Lithostrotian. Lonsdalia and the compound forms of Köninckophyllum.

ACTINOZOA RUGOSA.

- Gemmation by ova, simple and free.
  - tabula divided in two by a columellarian rod. septa of two orders. → Heterophyllum. Köninckophyllum. Acrophyllum.
  - septa of two orders, with columellarian rod. → Cyathaxona. Lophophyllum. Axophyllum. Dibunophyllum. Clisiophyllum.
- Gemmation by ova, simple and free. The floor of the calice is closed in by septa, lamellæ, and the interseptal and the interlamellar spaces, and closed in by interseptal dissepiments.
  - septa of two orders. → Densyphyllum. Fasiculophyllum. Centrocellulosum. Carcinophyllum. Histeophyllum. Aspidophyllum. Centrophyllum. Cymateophyllum. Albertia. Rhodophyllum.
  - septa of two orders, the columellarian area is occupied with a tube, and the calice is in the form of a double cup. → Aulophyllum. Cyclophyllum.
  - → Agassizia. Mortiera.

In tracing the generic relations of the corals of the carboniferous system, it seems to me to be the most natural and most interesting method to begin with the simpler forms, and, if possible, trace how they diverge and pass into other allied genera. Then I shall take in rotation those groups which possess characters which are more or less foreshadowed in the preceding genera. In following out this method, it will be necessary to briefly describe the generic characters of each, to refer shortly to the author of each genus, and also to those authors whose opinions are at variance with the structural details as seen by me. I shall accordingly begin with the genus *Aulopora* and its allies.

As regards the relationship of the genus, *Aulopora* may be said to be distinguished by characters of an exceedingly distinct nature. But, like all the other genera of this great class, there are structural characters which merge into and unite them with allied forms, and which also diverge in different directions. Regarding these points considerable differences of opinion have been expressed by authors who have more or less devoted their attention and have tried to elucidate their histological relations.

In 1850 Milne-Edwards and J. Haime (Brit. Foss. Corals, introd., p. 76) places *Aulopora* and *Cladochonus* as belonging to the family *Alcyonidæ*, and gives the following reasons:—"The genus resembles *Cornularia* and *Sarcodictyon* in rising from creeping filiform anastomosing stolons, but differ from these by their thick calcareous polypidom."

Professor L. G. de Köninck (Nouv. Rech. sur les An. Foss., p. 148, Pl. IX.) defines *Aulopora* as being sessile, gemmation lateral, cylindrical, and dependent on one another; that the visceral chambers of the parent communicates freely with the young corallites; stria distinct or wanting. He remarks that the resemblance between certain species of the *Bryozaries* is so great that mistakes have been made in describing them, and in certain cases they are like *Syringopora*, which led Fischer de Waldheim, and likewise Edwards and Haime to associate the two genera with each other. At p. 154, he describes the characters of *Cladochonus*, and states that the French actinologists and the generality of naturalists of the other countries, place this latter genus with the *Aulopora*, and further states that it seems erroneous to place *Cladochonus* and the genus *Pyrgia* as belonging to one genus, and regards *Pyrgia* and *Aulopora* as distinct in their character.

Professor Nicholson, in his work upon Tabulate Corals, p. 219,

asserts that there are tabula in typical forms of *Aulopora*. He combats the views of E. and H. that *Aulopora* has any relation with the genus *Syringopora*. His reasons are that *Aulopora* is parasitic, and that *Syringopora* throws up numerous erect corallites from the basal network, and that the network has a separate existence from the erect tubes, as it is usually found. And, at p. 222, he asserts "that there is no reasonable doubt that the genus *Pyrgia* (E. and H.) is really founded upon forms of *Cladochonus* (M'Coy), and therefore must be withdrawn in favour of the latter genus." And, at p. 223, he refers to the generic characters of the genus *Monilopora* (N. and E.), in which he includes only that curious *Cladochonus crassa* (M'Coy), and refers to its earlier development, and states that it commences in the form of a ring and encircling the column of a crinoid. He bases their generic characters upon the wall being thick, and by the presence of delicate concentric layers of sclerenchyma, and united by numerous cross-bars of trabecula. Further, he states, if he is correct in referring *Syringopora* to the perforate corals, then the *Auloporida* has no alliance with the *Syringoporida*.

In consequence of the remarkable conclusions expressed in the communication by Nicholson and Etheridge, jun., and subsequently repeated in Dr. Nicholson's Memoir, I have deemed it advisable to insert at greater length both generic and specific descriptions of the group than in ordinary circumstances I would regard as necessary, in order to show that the structural characters upon which they base their genus *Monilopora* may be more or less found in all the varieties of *Cladochonus* that I have examined. The specimens I have examined are numerous—at least, several hundreds. Their mistake must have arisen from the fact that the specimens they examined had been rendered imperfect from fossilization. It is therefore not without considerable hesitation that I have to express an opinion at variance regarding the creation of the genus *Monilopora* as distinct from *Cladochonus* (M'Coy), and also, the deleting of the genus *Pyrgia* (E. and H.). I have in vain sought for characters sufficiently distinct to warrant their deductions, and conceive that *Cladochonus* must be the generic name for the group. The structure referred to as occurring in the sclerenchyma of (*Monilopora*), *Cladochonus crassa* (M'Coy), may be detected in microscopic sections. In all the specimens I have examined (which, I may say, are numerous—at least, several hundreds), I believe that that genus must be

abandoned. I believe that, where there is a continuous series of the different varieties of the genus *Cladochonus* to examine, there is no palæontologist that will establish generic distinction upon details of structure that seems to me to be nothing more than specific characters. True generic distinction can only be well founded upon structure which is clearly indicated throughout a group. It may be objected that the limitation of generic relations depends in a great measure upon preconceived views, and that there are points upon which naturalists disagree in their estimate of the structural characters. This is well demonstrated in the group under consideration; but, let those who think that they may divide organic remains as they please, try to distinguish the different characters of the group, and the condition they are found in, and I venture to assert that they will be more particular in their definition, and will perceive how each group varies, and how chaotic are the accumulations of genera founded upon simple modifications of structure, and more especially upon the structural characters found in the septal zone, and they will soon find out that, to establish a genus with any degree of satisfaction, it is absolutely necessary to examine a large series of specimens. They will discover that, if every modification in the structural details of the peripheral zone is to be considered as the basis of a distinct generic group, the number of genera will be increased beyond measure.

In order that this may be clearly understood I will briefly describe the generic and specific relations of the specimens lying before me, and try and show their generic distinction, and how they merge in their generic characters into other allied groups, and how their development indicates central types which diverge in different directions. And in order that their relationship may be clearly indicated, I will, in the first place, notice the structural character of those forms which form central types, and then refer to the group that diverge on the one side. Afterwards I shall describe those whose structural details indicate a divergence in the opposite direction. Although this may not seem to be a connected series, yet, I venture to say, that it is the only method that can be adopted in order that their progressive development and their disposition to divergence can be clearly indicated.

HYDROZOA.

FAMILY AULOPORIDÆ.

Genus AULOPORA. (Goldfuss.)

Generic Characters.—Corallum compound, cylindrical, and composed of encrusting frondescent and more or less closely-aggregated tubular offsets from the lateral margins of the central tubular corallite and reticulate tubular expansions. All the young corallites are kept in union with one another by the epitheca, with an axial canal in free communication with the tube of each of the young appended corallites. The calice is deep and slightly raised above the encrusting corallum. In some forms the calice is up-curved at the distal end of the cylindrical corallum. In the reticulate varieties the calice is usually situated at the point of bifurcation, and the elevation of their margins is variable, usually from a third of a line to a line in height. The epitheca is smooth, and there are delicate annulations of growth. The endotheca forms the inner boundary of the more or less dense granular sclerenchyma. The space between the epitheca and the endotheca is occupied by granular sclerenchyma which is less dense, which in a tranverse section has indications of extremely faint striæ.

Aulopora gigantea. (M'Coy.)

Plate III., Fig. 9.

Specific Characters.—Corallum compound, parasitic upon the under surface of *Phillipsastrea* radiata, and consists of a loose reticulate colony of cylindrical corallites, and there is free communication by the visceral chamber through the colony. The corallites are about half-a-line broad. The calice is wide and raised about half-a-line above the procumbent community, and situated at the junction of the parental tube and the young corallites. The epitheca is smooth, and there are faint annulations of growth. This species can at all times be distinguished by the procumbent reticulate aspect of the community and the position of the calicular cavity.

Formation.—Lower Carboniferous.

Locality.—Blackridge, Dumfriesshire. This is the only locality that I have discovered this species in.

Aulopora campanulata. (M'Coy.)

Plate III., Fig. 4.

Specific Characters.—Corallum compound, parasitic upon *Phillipsastrea*, and consists of closely-aggregated reticulate colonies of stout and short cylindrical corallites; diameter of the tubes, three-quarters of a line, and there is free communication between the parent and the young corallites. The calice is about the width of the diameter of the tubular corallites, and raised above the procumbent community fully half-a-line, and are closely aggregated together—indeed, their walls are often in union with each other. There is always one, and frequently two, calices at the junction of the reticulate corallites. The epitheca is smooth, and there are faint annulations of growth. The walls are stout, and the space between the epitheca and the endotheca is occupied by minute granular sclerenchyma, which is more or less arranged into striæ or pseudo-septa, and there are indications of minute trabecula uniting the pseudo-septa, and at the base of some of the corallites there are developed minute angular tabulæ, which is in the proportion of one tabulate form to twenty of those in which there are no tabula developed, and thus form an intermediate variety between the non-tabulate species of *Aulopora* and the allied tabulata.

This species is readily distinguished from *Aul. gigantea* by the smaller size of the reticulations, by the greater stoutness of their walls, and the fact that the calices are developed often in union with each other, and they are never so wide at their apex, and by the presence of the pseudo-septa imbedded in the granular sclerenchyma.

Formation—Lower Carboniferous.

Locality.—Found at Wistown, Lanarkshire; and Blackridge, Dumfriesshire.

Aulopora gracilis. (Thomson.)

Plate III., Fig. 1.

Specific Characters.—Corallum compound, minute creeping branched system of cylindrical tubes, which are slightly raised at the distal extremity of the procumbent parasitic colony. These tubular corallites are about one-fifth of a line in diameter, and there is free communication throughout the colony, the mesenteric

cavity being continuous from the parental tube into the young corallites. The calice is not more than the diameter of the tubular corallites are wide. The epitheca is smooth, and there are faint annulations of growth.

This species is usually parasitic upon the epitheca of cup corals, and is readily distinguished from the preceding species by its encrusting dendriform aspect and the small cylindrical corallites.

Formation.—Lower carboniferous.

Locality.—Found in Bathgate Quarry, Linlithgowshire; and at Broadstone, Beith, Ayrshire.

Genus CLADOCHONUS. (M'Coy.)

Generic Characters.—Corallum compound, cylindrical, and the walls are of variable stoutness, and always developed in the form of upright branching and reticulate colonies rising from one corallite, and bifurcating at various angles in the different species; and there is free communication between the parent and the young corallites by a prolongation of the visceral chamber of the former, and extending throughout the latter; and all are kept in union by the epitheca. The calice is deep and thin around the apex, and widely open at the distal extremity of each of the up-curved and more or less conical corallites. The epitheca is smooth, and there are delicate annulations of growth. The endotheca forms the inner boundary of the granular sclerenchyma. The intervening space is occupied by more or less dense sclerenchyma, which in some forms consists of pseudo-concentric layers, and in one variety there are a series of indistinct semicircular cells around and attached to the inner boundary of the epitheca, and all are united by minute granular tissue. In some forms the visceral chamber is free, whilst in others it is more or less intersected by vesicular tissue, which near the base of the visceral chamber is all but rectangular, and becomes elongated convex cellular tissue, extending upwards and inwards; and there is an irregular free space in the centre of the corallites. This cellular tissue is not always present. Plate III., Fig. 2, represents a portion of a large slab of limestone, which is literally crowded with this species; and throughout the entire width those forms with the vesicular tissue are in the proportion of one to four of the non-cellular corallites; and in all the specimens that I have seen, a similar proportion is

constantly present. We have thus in this group a transitional character, uniting on the one hand the genus *Aulopora*, and on the other merging into the genus *Syringoporidæ*.

Cladochonus crassus. (M'Coy.)

Plate III., Figs. 7, 8, and 8A.

Specific Characters.—Corallum compound, erect and branching colony, and basally fixed by the primary corallite to some foreign body (Fig. 8), and developed from one another by lateral budding (Fig. 8A), and the young diverge in opposite directions, and produces frondescent compound communities. The corallites are conical; they are slender at their base, and dilated at their superior extremity, and there is free communication between the parent and the young by the continuation of the visceral chamber into the tubular young corallites. Fig. 7 represents the inferior boundary of a group, indicating that they had encircled some perishable body, whose decay left the circular group free. The young are developed and diverge in different directions. The calices are broad and deep, the epitheca is smooth, and there are faint annulations of growth. The walls are stout and granular, which in a transverse section are seen to indicate pseudo-concentric layers, and united by granular tissue.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, near Lesmahagow, Lanarkshire, on the top of the encrinital limestone.

Cladochonus bacillarius. (M'Coy.)

Plate III., Fig. 6.

Specific Characters.—Corallum compound, erect and sparsely branched colonies. The stems are slender, and basally fixed to some foreign body, and developed by lateral budding, and the young diverge in different directions. The corallites are long and slender, and abruptly dilate at their superior extremity, and there is free communication beween the colony by the continuation of the visceral chamber. The walls are stout, and two-thirds of a line in diameter, and the visceral chamber is about a fourth of the total diameter of the corallum. The wall consists of granular

sclerenchyma, and there is a psuedo-concentric arrangement indicated and there are minute semicircular cells attached to the inside of the wall. The calice is about double the diameter of the stem, and extends laterally about half-a-line from the vertical plane of the tubes. The epitheca is smooth, and there are faint annulations of growth.

Formation.—Lower carboniferous.

Locality.—Found in Auchenskeoch Quarry, near Dalry, Ayrshire.

This species is readily distinguished from the preceding by the sparse development of the corallites, and by the long slender tubes. The wall is considerably stouter, and the visceral chamber is much more circumscribed.

Cladochonus giganteus. (Thomson.) Sp. nov.

Plate III., Fig. 5.

Specific Characters.—Corallum compound, large and erect reticulate branches, which rise from a basal corallum. The corallites are cono-cylindrical and stout, and the visceral chamber is in free communication throughout the colony. Gemmation is by lateral budding. The calice is slightly wider than the average diameter of the corallites. The walls are moderately stout, and the space between the epitheca and the endotheca is occupied by granular sclerenchyma, which exhibits a pseudo-concentric arrangement in a transverse section. The epitheca is smooth, with faint annulations of growth. Fig. 5 exhibits the external aspect of the species near the lower extremity, and at the distal ends the species is ground down to expose the structural character of the corallum.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, Kirkcudbrightshire.

This species is abundant at Arbigland, and associated with several species of *Syringopora* and *Lithostrotion*, and conjointly form one of seven fringing reefs that surround the only fossil atoll that has come under my observation. I believe that it is the first time that a fossil atoll has been recorded. By and by it is my intention to describe this remarkable discovery in detail; meanwhile I wish merely to record the discovery.

Cladochonus antiqua. (M'Coy.)

Plate III., Fig 3.

Specific Characters.—Corallum compound, erect, and the branches are developed by tripartite budding. The corallites are cylindrical and slender, usually about half-a-line in diameter, and slightly dilated at their distal ends, and there is free communication throughout the colony by the continuation of the visceral chamber. The walls are moderately stout and granular, and the concentric arrangement of the sclerenchyma is faintly indicated. The calice is about a half broader than the diameter of the cylindrical corallite. The epitheca is smooth, and there are faint indications of annulations of growth. Plate III., Fig. 3, is a transvese section of a slab from the main limestone of Braidwood.*

Formation—Lower carboniferous.

Localities.—Found in the main limestone at Braidwood, Lanarkshire; in Auchenskeoch Quarry, Dalry, Ayrshire; at Blackridge, Dumfriesshire, where it is abundant, and associated with *Syringopora* and other coralline remains; and at Arbigland, Kirkcudbrightshire, where it is abundant and associated with several varieties of *Syringopora, Diphyphyllum* and several varieties of *Lithostrotion*, and these go to form one of the circular reefs that surround a fossil atoll, and exposed on the shores of the Solway Frith.

Cladochonus Michelini. (Edwards and Haime).

Plate III., Fig. 19.

Specific Characters.—Corallum compound, erect, and the branches are developed by lateral budding, and present a more or less irregular reticulate colony. The corallites are cylindrical and slender. The walls are moderately stout, and the visceral chamber is, in some forms, more or less interrupted by slightly angular tabulæ at the base, which become more angular, and forms a system of elongated convex cells, convexity inwards and upwards, and attached by their upper ends to the inner boundary of the

* This specimen I received many years ago from Mr. John Hunter, of Braidwood, and have great pleasure in offering him my cordial thanks.

wall, and at their lower ends rests upon the convex face of the anteceding cell. The tabulate forms, in all the specimens examined by me, are in the proportion of one to four of the non-tabulate varieties, and thus form an interesting transitional variety between the genus *Cladochonus* and *Syringopora*. The calice is deep, and rarely exceeds the diameter of the cylindrical tubes of the corallites. The epitheca is concealed in the matrix, and is therefore wanting.

Formation.—Lower Carboniferous.

Locality.—Found at Howwood, near Paisley, Renfrewshire; and at Auchenskeoch, near Dalry, Ayrshire.

This species I discovered in 1858, and until I had obtained a more complete series of this group I regarded this species as belonging to the genus *Syringopora*. And now, after a careful examination of the group, I am persuaded that this species is a transitional form, and thus unites the genus *Cladochonus* to the simple forms of *Syringopora*, and is therefore readily distinguished from all the other varieties of the genus.

Cladochonus minutus. (Thomson.) Sp. nov.

Plate III., Fig. 2.

Specific Characters.—Corallum compound, minute, cylindro-conical, and in the form of delicate bifurcating small colonies. Gemmation by lateral buds. There is free communication through the visceral chamber into the young tubular corallites. Fig. 2 represents a ground section of a small slab, exhibiting a more or less confused mass, arising from the fact that they are imbedded in a somewhat soft friable shale; and it is rare that we find specimens showing the continuous bifurcated aspect. The calice is deep and broad at the distal end. The epitheca is smooth, and there are faint annulations of growth. The wall is thin at the apex, and becomes slightly stouter near the base, and consists of two layers of granular sclerenchyma, with less dense minute granular tissue between the epitheca and the endothecal layers.

Formation.—Lower carboniferous.

Locality.—Found at Auchenskeoch, near Dalry, Ayrshire; and at Blackridge, Dumfriesshire.

This delicate species is readily distinguished from all the other species of the genus by its tripartite aspect and by its minute and

delicate form. In the tripart arrangement of the corallites it resembles *Clad. antiqua;* but differs from that species in its more graceful minute form: and the corallites are never so large, and the walls are much more delicate.

At page 32 I stated that one of the species of *Cladochonus* possessed characters which clearly indicated a transitional tendency, and intimate relation with the genus *Syringopora.* We will, therefore, examine in a cursory manner that relationship, and, if possible, trace the transitional conditions in order to know whether development is varied, and wherein variation is indicated, and how far the evidence supports the inference that variation is universally distributed throughout the group.

FAMILY SYRINGOPORIDÆ.

Genus SYRINGOPORA. (Goldfuss.)

Generic Characters.—Corallum compound, cylindrical, and in more or less dense communities; and each is united by horizontal tubes through which there is free communication throughout the colony. Reproduction is by gemmation, and diverging in all directions from the primary corallite, and frequently met with in large dome-shaped masses. In the young corallites there are horizontal tabulæ, which merge into convex cellular tissue, arranged along the inner margin of the wall, and there is an irregular tube in the centre. Here and there, however, there are horizontal tabulæ, and more especially at the union of the connecting tubes. The epitheca is stout, and there are faint annulations of growth. The septa are developed in the space between the epitheca and the endotheca.

Syringopora laxa. (Phillips.)

Plate III., Fig. 23.

Specific Characters.—Corallum compound, and widely separated. The epitheca is stout, and there are faint annulations of growth. Reproduction is by gemmation, and diverge in all directions, giving rise to large masses, and each are connected by horizontal tubes, which are distant; and there is free communication throughout the colony by means of these tubes. At the base of the young

corallites there are rectangular tabulæ, which merge and become elongated convex cells, giving rise to a system of irregular convex cellular tissue around the periphery. The central area is tubular, and usually intersected by horizontal tabulæ at the union of the rectangular cylindrical tubes. The septa are hardly recognisable in the dense granular tissue that occupies the space between the epitheca and endotheca.

Diameter of the corallites, about a third of a line.

Formation.—Lower carboniferous.

Locality.—Found at Blackridge Quarry, Dumfriesshire.*

This is the most delicate, tall, slender form that I have met with in the carboniferous rocks of Scotland, and has only been found in this locality.

Syringopora gigantea. (Thomson.) Sp. nov.

Plate III., Fig. 24.

Specific Characters.—Corallum compound, and composed of long cylindrical and distant corallites, and united by distant horizontal tubes, through which there is free communication throughout the colony. The epitheca is moderately stout, and there are faint annulations of growth. There is a system of elongated convex cellular tissue around the periphery, and there is a central tube extending throughout each of the corallites. There are twenty minute septa, which are hardly recognisable.

Diameter of corallites, 2 lines.

Formation.—Lower carboniferous.

Locality.—Found at Langside, Beith, Ayrshire.

This species is readily recognised by its greater dimensions, and the septa are not so numerous as in *Syr. distans*, its nearest ally.

This species was discovered by Mr. Robert Craig, Langside, Beith, to whom I offer my cordial thanks for allowing me to add it to the list of carboniferous corals.

* The limestone in this locality is put down in the Geological Surveys Memoir as belonging to the calciferous sandstone. There, however, must be an error in placing it in that horizon, as the fauna found in that section is similar to what is usually found in the upper members of the lower carboniferous limestone. Indeed, there are corals found in that locality that have never been found even in the lowest beds; and I am therefore persuaded that that section has got confounded with the calciferous sandstone found in the neighbourhood.

Syringopora geniculata. (D'Orbigny.)

Plate III., Fig. 25.

Specific Characters.—Corallum compound, and composed of closely-aggregated cylindrical corallites, and connected by horizontal tubes, which are about a line apart; and there is free communication through the visceral chamber, and extends to the neighbouring corallites through the rectangular tubes. The epitheca is stout, and marked with encircling lines of growth, and geniculated at the origin of the tubes. The septa are numerous, and hardly recognisable in the dense sclerenchyma. There are twenty-four septa in each.

Diameter of corallites, 1 line.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, Kirkcudbrightshire.

This variety is found associated with *Cladochonus* and several varieties of *Lithostrotion*, and forms one of the fringing reefs that surround the atoll of that district.

Syringopora catenata. (M'Coy.)

Plate III., Fig. 28 and 28A.

Specific Characters.—Corallum composed of closely-aggregated, delicate, flexuous cylindrical corallites. Gemmation is lateral, giving rise to dense colonies, and united by numerous connecting hollow tubes; and there is free communication throughout the mass by means of the connecting tubes. There is a system of minute convex cells around the periphery, and there is a central free space. The epitheca is stout, and marked with annulations of growth. The septa are hardly recognisable in the dense sclerenchyma.

Diameter of corallites, half-a-line.

Formation.—Lower Carboniferous.

Locality.—Found at Blackridge, Dumfriesshire.

Syringopora distans.

Plate IV., Figs. 8 and 8A.

Specific Characters.—Corallum compound, and composed of cylindrical corallites, and connected by distant hollow tubes.

Gemmation is lateral, and there is free communication throughout the visceral chamber, and extended through the connecting tubes throughout the colony. The epitheca is thin, and marked with encircling lines of growth, and geniculated at the origin of the connecting tubes. The septa are numerous, and hardly recognisable in the dense sclerenchyma.

Diameter of corallites, 1 line.

Formation.—Lower carboniferous.

Locality.—Found at Boghead, Lesmahagow, Lanarkshire.

I might have included descriptions of other two species that are in my cabinet—*i.e.*, *Syr. ramulosa*, and *Syr. reticulata*. These, however, are poorly preserved, and I deem it expedient not to include them till I procure others in better preservation. I may state, however, that *Syr. ramulosa* is composed of closely-aggregated cylindrical tubes, that gemmation is lateral, and that the walls are never so stout, and the septa are not so numerous as in *Syr. geniculata*, its nearest ally; and that *Syr. reticulata* is found in large masses, and the *reticulation* is very pronounced; the walls are stout, and tabulæ approximate more closely to the *Cladochonus Michelini* (E. and H.), and may thus be said to be the species that approaches more closely in its structural details to the genus *Cladochonus* than do any of the other species of that genus.

With regard to the relationships and zoological position of *Syringoporidæ*, a careful comparison of the structural details leaves no doubt that it is singularly characteristic and distinctly pronounced in its structural details, and may be regarded as uniting the genus *Aulopora* on the one hand, by the possession of rectangular tabulæ at the base of the young corallites; and have a more or less close relation to the genus *Michelini*, of Köninck; and the vesicular tissue in the peripheral zone may be regarded as foreshadowing the broad zone of vesicular tissue, which is considerably more developed in the genus *Thysanophyllum* of Nich. and Thom. Though there is thus a more or less near relation between those diverse groups, in each, however, there are central types clearly pronounced in the generic characters; and amongst the different species there are divergent forms which merge and unite into other groups, which, when more fully developed, assert their generic characters in a more or less pronounced manner. I am, however, convinced that with more careful investigations, other

forms will yet be discovered that will more closely unite the genus *Michelini* to that of the genus *Syringopora*. While there is thus indicated transitional relationships in the groups referred to, yet there are structural differences to be noted, which leave no doubt as to their true zoological position, which will be briefly referred to:—The genus *Cladochonus* agrees with *Syringopora* by the fact that each are reproduced by gemmæ, and are in upright communities. There is free communication throughout the visceral chamber of the colonies, and in the young of *Syringopora* there are rectangular tabulæ similar to the tabulæ that are present in *Aulopora*. *Syringopora* differs in the more advanced stages of development; these are always united by rectangular connecting hollow tubes, and by the presence of the zone of vesicular tissue that is more or less developed around the peripheral zone. *Syringopora* is remotely related to the genus *Michelini* by being developed by gemmæ, and by the fact that each are in upright communities; and in *Michelini*, the vesicular zone of *Syringopora* is foreshadowed in the much less developed vesicular tissue in the peripheral zone of *Michelini*. The latter genus, however, is separated by the presence of minute mural pores, and the more or less rectangular tabulæ largely predominates; and from *Thysanophyllum* is separated by the development of short lamellar septa, which are intercepted by the dense vesicular tissue that is developed between the septa and the periphery, and there are always rectangular tabulæ in the central area, and the corallites are all more or less fused by their walls, and consequently polygonal in form; while in *Syringopora* the septa are minute, and extend from the periphery to the zone of vesicular tissue, and there is more or less free communication by the prolongation of the visceral chamber, and transmitted throughout the colony by the cylindrical tubes, and the tabulæ are very irregular. Upon the whole, while the relationship of these groups are more or less connected, yet their structural details clearly indicate generic distinction, which, with further development, are seen to merge, and to unite their generic relation by transitions of an extremely important character; and thus clearly indicates the fundamental principle that variation is their natural and constant character, and clearly demonstrated throughout the relationship of these groups.

Genus PYRGIA. (Edwards and Haime.)

Generic Characters.—Corallum simple, small cornute. The epitheca is moderately stout, and there are faint annulations of growth. The calice is deep and circular. The septa (pseudo-septa) are represented by faint lines or striæ. They do not coalesce in the centre of the calicular fossa.

This is the only species that I have yet discovered—*i.e.*, *Pyrgia Labechia* (E. and H.). Plate III.

The corallum is 2 lines long; diameter of calice, 1 line.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

This delicate little specimen is readily distinguished from any of the preceding genera by its simple form and the presence of pseudo-septa along the inner boundary of the wall.

Frequently only single or independent examples of *Aulopora* and *Cladochonus* are found, but these corals must, nevertheless, be considered as compound forms. Sometimes single specimens are found, showing buds or gemmæ bursting from the lateral margin of the parent coral (Pl. III., Fig. 8A). Still, I have never met the single form of either of the genera presenting a similar external aspect; and in no instance is there exhibited the pseudo-septa along the inner face of the wall so distinctly marked as we find in the genus *Pyrgia*, and the latter has always the usual appearance of a simple coral. Indeed, from the structural details of the genus, it may be said to be an intermediate group, which unites the genus *Cladochonus* on the one hand, and, on the other, it merges so near to the genus *Protocyathophyllum*,* that I am

* The genus *Protocyathus* was established by myself, and published in the *Proceedings* of the Philosophical Society of Glasgow in 1880, for the reception of a group of corals in which the septal system is first seen to extend into the centre of the visceral chamber. As, however, the genus *Pyrgia* (E. and H.) was formerly established by these eminent authors to include a simple coral, in which the septa are represented by minute striæ—foreshadowing the septal system of more highly-developed forms, for which the latter generic name might have been appropriately assigned—therefore, in order that the generic distinction may be clearly defined, and to prevent any confusion arising from their generic relationship, I propose to make an alteration in the name of the latter, and will in future designate the group by the generic name of *Protocyathophyllum*, which, I believe, more fully expresses the generic characters of the group.

inclined to regard the transitional characters as having been induced by innate tendency to variation in the polyp. The genus *Pyrgia* differs from *Cladochonus* in being always simple and free, and the walls are never so stout; while, in *Cladochonus*, the corallum is always developed by gemmæ, and is always in compound communities, and therefore *Pyrgia* cannot be further associated or confounded with the genus *Cladochonus*. While the genus *Pyrgia* agrees with *Protocyathophyllum* in being simple and free, and the pseudo-septa is the prototype of the more highly-developed septal system of the latter, it, however, differs from the latter in the fact that, *Protocyathophyllum*, the septal system is well indicated, and extends, in the more highly-developed forms, into the centre of the calicular fossa. In, however, some species of the latter the septa are rudimentary, and rest upon the superior face of the tabula, and therefore must be regarded as an intermediate and distinct genus.

As regards the genus *Cladochonus* (M'Coy), I have found great difficulty in defining the line of demarcation between it and the genus *Aulopora* (Goldfuss). The transitional conditions pass into each other by gradations so minute that to separate the larger varieties of *Aulopora* from the smaller species of *Cladochonus* can only be accounted for either from the innate tendency to variation in the animals that secreted these remains, or variation induced from the altered conditions of the surroundings. In the general arrangement of the granular sclerenchyma, and the continuity of the visceral chamber in the parent tube, and its extension throughout the colony in *Aulopora*, it presents a close resemblance to those forms which are regarded as properly belonging to the genus *Cladochonus*. But these are, nevertheless, separated by characters sufficiently distinct to warrant them being retained as separate and distinct genera.

In the species *Aulopora gracilis* (Thom), Plate III. Fig. 1, the corallum is in the form of a creeping branched system of cylindrical tubes, attached by the whole of their lower surface to the theca of a cup coral, and it is only at the superior extremity of each corallite that the calice is slightly raised above the prostrate colony; while in *Aulopora gigantea* (M'Coy), Plate III., Fig. 9, the groups are in the form of reticulate, wide-apart, creeping communities, in which the terminal portion of each corallite is situated at the union of the successive corallites, and are a little more raised above the tubular corallite than in the preceding species. The walls of the latter

are stouter than is found in the former. In, however, *Aulopora companulata* (M'Coy), Plate III., Fig. 2, the reticulations are never so far apart, and usually at the angles of union there are sometimes two and three corallites, and in this species the calices are raised much higher than in either of the preceding species. In this species, near the base of some of the corallites, there is developed minute angular tabulæ, which indicate a transition from *Aulopora* into the tabulata. In all, the granular sclerenchyma is more or less developed, and the radiate tissue is faintly observed; while in *Aul. companulata* there is a considerable increase in the density of the sclerenchyma, and the septariæ is greatly more pronounced.

In the genus *Cladochonus*, although the development is from lateral buds, and produces erect compound branching reticulate colonies, there is, however, considerable difficulty in defining the structural difference between the minute forms of *Clad. minutus* (Thomson), Plate III., Fig. 2, and the less frondescent forms of *Aul. gracilis*, Plate III., Fig. 1. In *Clad. antiqua*, Plate III., Fig. 3, there is a considerable increase not only in the size but also in the density of the sclerenchyma. In *Clad. bacillarius*, Plate III., Fig. 6, the corallites are considerably large, the calicular cavities are further apart, the sclerenchyma is much denser, and the septaria is observable; and the indications of a system of semi-concentric cells around the inner margin of the wall indicates a considerable increase in the structural development.

In *Clad. crassus* (M'Coy), Plate III., Figs. 7, 8, and 8A, the corallites are considerably larger, and the pseudo-septa are more pronounced, which led Dr. Nicholson to establish the genus (*Monilopora*) for its reception; and I believe, if he had had the entire series to examine, he would not have founded a new genus upon structure which characterises the whole group. In *Clad. gigantea* (Thomson), Plate III., Fig. 5, the corallum is greatly increased in size, the walls are stout, and pseudo-septa are observable, and near the base of some of the corallites there are one, and, in some forms, two curved tabulæ, which, in a transverse section, presents the form of a semicircular plate.

In *Clad. Michelini*, Plate III., Fig. 21, the corallites are smaller, the walls are greatly stouter, and the pseudo-septa are more or less distinct, and there is convex cellular tissue developed along the inner margin of the wall, and there is an irregular tubular area in the centre of the visceral chamber.

The vesicular tissue is found in the proportion of one to four

of the non-vesicular forms characterised in the vesicular varieties, which indicate transitional conditions which could only be induced from an innate tendency in the animal to variation, and which merge to and unite the vesicular varieties to the simpler form of *Syringopora*. It will thus be seen that the above characters are sufficiently distinct to warrant the groups being retained as distinct and separate genera, and have also clearly indicated a series of minute transitions, which leads from the one group into the other; and, I believe, with further research, other intermediate forms will be discovered which will not only well repay for the attention necessary, but will also aid in elucidating that development has been brought about by slow and innate tendency to variation in the living tissue of the animal's body that secreted these organic remains.

The next group which falls to be noticed in an ascending series includes that interesting genus, *Protocyathophyllum*, which has been referred to as being closely allied to the genus *Pyrgia* (E. and H.).

Genus Protocyathophyllum. (Thomson.)

Generic Characters.—Corallum simple, small, conical, and slightly curved. The epitheca is of variable stoutness, and there are delicate encircling lines and shallow annulations of growth. The calice is circular and deep, and in some forms extends to the base of the corallum, whilst in others it is circumscribed by a more or less irregular tabulæ. The septa are of two orders. In those forms in which the calice is deep, the primary septa are well developed. The younger coalesce with the older near the base of the corallum, the primary extends inwards, bend upwards, coalesce, and form a loose cellular reticulate structure in the centre of the calicular fossa. The secondary septa are small and hardly recognisable, and each is incompletely united by sparse interseptal dissepiments; whilst in those forms in which the depth of the calice is circumscribed, the septa are rudimentary and slightly raised at their inner ends, and form a more or less convex irregular tabulæ, crowned with rudimentary ridges, which converge to the centre of the visceral chamber. The latter would seem to have been formed by the unfolding of the wall of the polyp. The fossula is small and of variable depth.

These small and delicate simple corals present characters alike

interesting to the biologist and palæontologist. In one of the forms (Plate III., Fig. 14) we have only four rudimentary septa developed, forming the prototype of the septal system of the rugosa corals, and which suggested to me the generic name. In other forms there is a greater number of septa developed. In all cases they are multiples of four, and bilamellar, and with their increase in size and number there is a proportionate increase in the development of the interseptal dissepiments, whilst in the simpler forms the interseptal dissepiments are represented by rudimentary ridges. As regards the classificatory value of the group, I did regard the first-discovered specimens as belonging to the genus *Pyrgia* (E. and H.). Subsequently I discovered a greater number of forms which presented characters sufficiently distinct to warrant me in classifying them as a separate group, whose relations are *Pyrgia* on the one hand, and *Amplexus* on the other. They also present characters which have a close affinity to the genus *Densyphyllum Dibowsky*, and some of the forms have a close ally in the genus *Zaphrentis* (Sowerby).

As regards the relationships of this group, they may be distinguished by characters of a fundamental nature, and in order that their relationship be clearly defined, I will briefly note the structural characters of the species selected from the group, which may be summarised according to the relative value of the septal system in an ascending series.

Protocyathophyllum quadrophyllum. (Thomson.)

Plate III., Fig. 14.

Specific Characters.—Corallum simple, small, cylindro-conical, and curved. The epitheca is thin and smooth, with irregular annulations of growth, and there are several tubercular projections. The calice is deep; the septa are rudimentary and converge to the centre, and are seen on the crown of the tabula in the form of slightly-raised ridges. There are four primary septa, and the interseptal spaces are minutely mammillated, indicating the development of an extended septal system.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

This interesting little species was in my possession for a considerable time before I could decide into what group it ought to be placed.

At first I did regard it as belonging to the genus *Lithostrotion.* Having since examined, with considerable care, fragments of the lower extremities of the different varieties of that genus, I have found that in all cases the septal system of this group is developed immediately after the secretion of the epitheca at the base of each corallite—thus indicating that this interesting specimen is not only the type of the genus, but in it there is the first indication of the tetramural arrangement of the septa, and placing beyond all doubt the fact that the septal system of the rugose corals are multiples of four and that the septa resting upon the rudimentary tabula are characters that unite this group with the genus *Amplexus.*

Protocyathophyllum plicatum. (Thomson.)

Plate III. Figs. 15 and 15A.

Specific Characters.—Corallum simple, more or less conical, and slightly curved. The epitheca is thin, smooth, and there are longitudinal ridges and plications. The calice is deep, and extends to the base of the corallum. The septa are rudimentary, and a portion of them pass to the inferior extremity of the corallum. There are eight primary, alternating with an equal number of secondary septa, and the interseptal dissepiments are indicated by faint and hardly recognisable transverse ridges and depressions, and the fossula is large. Two rudimentary septa of shorter length than the others extend in to it.

Height of corallum, 8 lines; diameter of calice, 4 lines.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

Formation.—Lower carboniferous.

In this interesting and unique species there is not only a further increase of the tetramural arrangement of the septa, but there are introduced rudimentary interseptal dissepiments, indicating not only more complex structural details, but also illustrating the innate tendency to variation in the tissue of the living animal, and it has a close relation to the genus *Pyrgia.*

Protocyathophyllum spinulosum. (Thomson.)

Plate III., Fig. 12.

Specific Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is thin and continuous on the one side of

the corallum, while on the other it is interrupted in the middle, and assumes a semicircular double cup, which may have been produced by the altered conditions of the surroundings, and rupturing a portion of the polyp's body from the sclerodermic matter, thus involving the fission of a portion of the parent calice on the one side, while the original coral continued to grow uninterruptedly on the other. There are encircling lines and shallow annulations of growth, and on the ventral side of the corallum there are numerous spinous projections. The calice is deep, extending to near the base of the corallum. The septa are indicated by faint lines at their superior extremity. A portion of them converge to the centre at the base of the calicular cavity. There are eight primary, alternating with an equal number of secondary septa, and each is united near their inner ends by a transverse plate, which converges inwards and downwards towards the base of the calicular cavity.

Height of corallum, 6 lines; diameter of calice, 2 lines.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

This remarkable species indicates a near relation to the genus *Densiphyllum Dibo.*, by the fact that the septal system converges to the centre of the calicular cavity, and thus not only foreshadows a transition from this simple group, in which the calice extends to the base of the corallum, but also foreshadows the septal characters of the genus *Cyathophyllum*, by the septa converging into the centre of the calicular cavity, but differs from the latter in the absence of tabulæ.

Protocyathophyllum elegans. (Thomson.)

Plate III., Fig. 18.

Specific Characters.—Corallum simple, small, cornute, and conical. The epitheca is thin, smooth, and there are shallow annulations of growth. The calice is deep, and extends to the base of the corallum. The septa are well developed, and a portion of them extends to the base of the calicular cavity, whilst others stop short and coalesce with older septa. There are twenty septa, and there are faint indications of interseptal dissepiments. The floor of the calicular cavity is slightly raised, and there are delicate ridges produced by the slightly-elevated inner ends of the older septa.

The fossula is small, and one of the primary septa, of shorter length than the others, extends into it.

Height of corallum, 3 lines; diameter of calice, 2 lines.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

This elegant little species possesses characters which clearly indicate a divergence in both directions, in foreshadowing the tabulata, in the slightly-elevated floor of the calicular cavity on the one hand, and shows a tendency to merge into the *Cyathophylloidæ* by the presence of delicate ridges produced by the slightly-elevated inner ends of the older septa on the other.

Protocyathophyllum Verrilliense. (Thomson.)

Plate III., Fig. 16.

Specific Characters.—Corallum simple, turbinate, and curved. The calice is broad and deep, and extends to the base of the corallum. The epitheca is thin and smooth, and there are shallow annulations of growth. The septa are well developed, and of two orders. There are thirty primary, alternating with an equal number of secondary septa. The latter are delicate, and extend inwards for a third of the length of the primary septa. A portion of the primary septa unite at the base of the visceral chamber, and form a loose reticulate structure, and the centre of the central area is small. The interseptal dissepiments are few in number and well developed. The fossula is large, and one primary septa, of shorter length than the other, extends into it.

Height of corallum, 5 lines; diameter of calice, 4 lines.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

In this species the vesicular tissue, so abundantly developed in other genera to be noticed, is indicated.

Protocyathophyllum Dalryense. (Thomson.)

Plate III., Fig. 17.

Specific Characters.—Corallum simple, small, turbinate, and curved. The epitheca is smooth, and there are shallow annulations of growth. The calice is deep, and extends to near the base of

the corallum, and its floor is reticulate. The lip is everted. The septa are well developed, and about half their length down from the superior extremity they abruptly project inwards, and thus circumscribe the calicular fossa. There are twenty primary, alternating with an equal number of secondary septa. The latter extends inwards for a third of the length of the primary septa, and each is united by interseptal dissepiments. A portion of the primary septa curve upwards, and coalesce at their inferior extremity, and form a dense reticulate structure in the centre of the floor of the calicular fossa. The fossula is small, and one of the primary septa, two-thirds of the length of the others, extends into it.

Height of corallum, $3\frac{1}{2}$ lines; diameter of calice, $2\frac{1}{2}$ lines.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham Baidland, Dalry, Ayrshire.

In this interesting species there is foreshadowed the broad interseptal area by the presence of the abrupt projections of the septa about their own length from their inner ends, which not only circumscribe the calicular cavity, but, by the dense reticulate tissue in the centre of the calicular cavity, not only foreshadows the broad interseptal chambers, but also indicates a further development of the structural details of the central area—thus indicating a further development of the structural details of the corallum.

Protocyathophyllum Charlestonense. (Thomson.) Sp. nov.

Plate III., Fig. 22.

Specific Characters.—Corallum tall, simple, cylindro-conical, and curved. The epitheca is thin and smooth, and the septa are indicated through the thin epithecal covering. The calice is remarkably deep, and extends to within half-an-inch from the base. The septa are stout, and project about 3 lines inwards; they then descend down to near the base of the corallum. A portion of them coalesces and becomes united to the older septa; the latter converge into the centre of the calicular cavity and more or less unite, and there are indications of some of the septa curving and forming the wall of the fossula. There are forty septa, which are thin, around the periphery; they then become stout, and at their inner ends become thin and pointed, exhibiting a clavate aspect, with a thin point at their outer ends, where they are united by

sparse interseptal dissepiments. The septa are lamellar, and there are faint indications of the interlamellar plates *(Trabicula)*. The fossula is large and extends into the centre of the calicular cavity.

Height of corallum, fully 6 inches; diameter of calice, 1½ inch.

Formation.—Lower carboniferous.

Locality.—Found in Charleston Quarry, on the top of the thick bed of limestone. Indeed, this is the only locality where I found this remarkable coral, and when first discovered I did regard this corallum as belonging to the genus *Zaphrentis*. At subsequent visits I did procure other and better preserved specimens, which indicated that it had a near relation to the latter genus, although on the whole the structure clearly indicated a more intimate relation to the genus *Protocyathophyllum*.

In consequence of the remarkable characters of this genus, I have described the specific characters more fully than I otherwise deem it desirable. In the group we have the septal system developed from the most rudimentary conditions through a series of stages which may be summarised as follows:—

(1) In *Prot. quadrophyllum*, by the presence of the four rudimentary septa resting upon the superior face of the tabulæ—thus clearly showing the tetramural development of the septa, and establishing its rugose character, and, by the presence of the tabulæ, clearly indicating its alliance with the genus *Amplexus*.

(2) In *Prot. plicatus*, by the fact that the eight septa are rudimentary and the interseptal dissepiments are faintly indicated—thus uniting by a more fully-developed septal system the group to the genus *Pyrgia* (E. and H.).

(3) In *Prot. spinulosus*, by the fact that the septa are more fully-developed, and a portion of them converge to the centre of the calicular cavity; and thus indicate a transitional variety between the group and the genus *Densiphyllum Dibos*.

(4) In *Prot. Verrilliense*, in the septal system, there is a considerable increase in their number; and a portion at their inner ends unite and form a more or less reticulate structure.

(5) In *Prot. Dalryense* the septal system are not only more highly developed, but a portion of them coalesce at their inner ends, and form a dense reticulate structure, and thus foreshadow the reticulate aspect in the central area of the genus *Carcinophyllum* (N. and T.).

(6) In *Prot. Charlestonense* the septa are greatly more developed, and the extension and union of a portion of them at their inner ends—their approaching, uniting, and folding round to form the wall of the septal fossula—clearly indicates a transitional variety from that group into the genus *Zaphrentis*. There are other modifications which I might have noticed; but believe that what has been noted will be sufficient to establish the conviction that modification is an inherent character, and that there is a constant and persistent tendency to diverge and to unite each group in different directions.

The next group which falls to be considered is the genus *Alveolites;* and I hope to be able to show that in the genus *Aulopora* there is an alliance to *Alveolites* indicated in the presence of the tabulæ in one of the species of that genus.

Genus ALVEOLITES. (Lamarck.)

Generic Characters.—Corallum compound, composed of closely-aggregated spherical corallites, when free from lateral pressure. When affected by lateral pressure they are prismatic, and more or less arranged in superimposed layers. Calices circular when free from lateral pressure; they are, however, usually oval, triangular, pentagonal, hexagonal, and heptagonal in the large compound masses, where they are more or less affected by lateral pressure. The walls are perforated by irregular mural pores. The increase is by fissiparity. In some instances it is found in irregular flat sheets, and terminating at a point in the under surface. It seems to have been attached to foreign bodies, and covered with a wrinkled epitheca; whilst other forms are pyriform, irregularly hemispherical, and mammillar-encrusting masses. I have a specimen eighteen inches broad, as a mere thin encrusting sheet, with a continuous series increasing in height up to fifteen inches, and ten inches in diameter.

When referring to the structural characters of the genus *Aulopora*, page 27, we find that in that genus there was a series of developmental stages, and that the species *Aul. companulata* (M'Coy) not only possessed characters which clearly belonged to the genus *Aulopora*, but in some of the corallites there are developed minute transverse tabula, which indicates that in that

species there are transition conditions, which merge and unites the *Tubulosa* with the *Tabulata*. Although the *Tabulata* is thus foreshadowed in that species, I am persuaded that other varieties will yet be discovered, that will not only more closely unite those genera, but will indicate other transitional forms that will merge into other allied groups. With our present knowledge, the group that falls to be considered in consequence of their tabulata character, and in which the septal system is either foreshadowed or wanting, and thus have the nearest relation to that species is *Aulopora*, in which the rectangular tabulæ are present. Although this species has a close relation to certain species of *Cladochonus*, yet, from the fact that the tabula are rectangular, I am disposed to regard *Alveolites* in an ascending series to have near relations to the *Tabulata* species of *Aulopora*.

While the relationship of these genera are so closely united by the presence of transverse tabulæ, there are important characters in the genus *Alveolites* that is never found in the genus *Aulopora*. The genus *Aulopora* is parasitic, developed by gemmæ, and composed of cylindrical corallites, and in compound communities, and there is a total absence of mural pores. While the genus *Alveolites* is also composed of cylindrical coralites, the genus is however developed by fission, and mural pores are always present.

These points may be briefly summarised as follows :—*Aulopora* may be readily distinguished (1) by the fact that the compound communities are always in parasitic encrusting sheets; (2) the development is always by gemmæ; (3) the total absence of mural pores.

And *Alveolites* may be at all times distinguished by (1) the form and aspect of the corallum being always in compound communities, and the corallites are tabular and erect; (2) the development is by fission, and (3) mural pores are always present. It will thus be apparent that the genus *Alveolites* has near relations to *Aulopora*, yet it possesses characters sufficiently distinct to warrant it being regarded as a separate genus, and which present the following specific characters :—

Alveolites septosa. (Edwards and Haime.)

Plate IV., Figs. 3, 3A, and 3B.

Specific Characters.—Corallum in broad encrusting sheets, in spherical and pyriform masses, and more or less mammillated, and.

frequently found encrusting the ventral valve of *Productus giganteus*. The corallites are pentagonal and hexagonal, and are a third of a line in diameter, and from five to eleven lines long. The tabulæ are well developed, and there are from four to six in the space of a line. In some forms along their interior there are rows of minute elongated granules, whilst in other forms they are almost destitute of the granular structure. There are mural pores, and of large size, which alternate between the granular rows. They are developed by fissiparity, and the teeth-like projections may be seen in well-preserved specimens as minute points, and can be traced extending across the calice and becoming attached to the opposite wall.

Formation.—Carboniferous.

Locality.—Found at Catscraigs, Dunbar, Haddingtonshire; Petershill, Bathgate; Wiston and Boghead, Lesmahagow, Lanarkshire; and Garsewater and Asheyburn, near Muirkirk, Ayrshire.

In this genus I do not deem it necessary to describe in detail each of the species that are found in the carboniferous system. For full details I beg to refer to my paper, published in the *Proceedings* of the Philosophical Society of Glasgow, 1881. In order that we may have as clear a conception of the different structural characters as our present knowledge will permit of, I will briefly point out wherein each of the species differ, and wherein there is indicated transitional conditions, and what forms seem to be their nearest allies—and in rotation, as each was described by the different authors. In the four species that have been discovered in the carboniferous limestone series, all are more or less similar in their mode of development, in their external aspect, and in the presence of tabula. They, however, present in all the species structural details which indicate specific distinction, but which, in a large series, each species are seen to merge by almost imperceptible gradations into their nearest allies, and to diverge in different gradations.

In *Alveolites septosa* (E. and H.), the corallites are about a third of a line in diameter, and from five to eleven lines long, and there are from four to six tabulæ in the space of a line. One variety of this species is rough and granular, and in external aspect resembles *Favosites*, but, when sectioned, we find the fissiparous mode of development throughout the mass—a characteristic which is always present in *Alveolites*, and quite distinct from the structure of *Favosites;* but which indicate a transitional

condition which, with further development, would merge into the genus *Favosites.*

Alveolites depressa. (Edwards and Haime.)

In this species there are from ten to fourteen corallites in the space of a line, and from three to five lines long, and the tabulæ are a seventh of a line apart. This delicate species is found in flat encrusting sheets at Charleston.* I have one sheet eighteen inches in diameter. It is also found in dome-shaped masses of considerable dimensions. For a considerable time after my first discovery of this species in Charleston, I was inclined to place it as belonging to the genus *Chætetes*, but finding the mural pores and the fissiparous development, I felt satisfied that it could not be placed amongst that genus, and may be regarded as possessing characters which, with further development, indicating a transitional condition, which with further differentiation will merge into the simpler varieties of *Chætetedæ.*

Alveolites capillaris. (Phillips.)

In this species there are from six to ten corallites in the space of a line, and from three to seven lines long, and the tabulæ are about a seventh of a line apart. From the near approximation of this species, I was long disposed to regard it as a variety of *Alv. depressa;* but from the examination of a large series of specimens, I have placed it as a distinct species, which may be regarded as an intermediate variety between *Alv. septosa* and *Alv. depressa*, and which can be traced diverging in opposite directions; and beg to state, that it gives me the greatest pleasure to corroborate the classification of the eminent and amiable author, Prof. John Phillips.

Alveolites Etheridgeii. (Thomson.)

There is no species of the group that presents more distinctive, and yet more varied characters than this one. The corallites are extremely varied and large. Some are pentagonal, hexagonal, heptagonal, and sub-rhomboidal; some are one line, whilst others are a third of a line in diameter. They are here and there arranged throughout the mass in substellate groups, radiating irregularly

* This is *Chætetes hyperboreus* of Nicholson and Etheridge.

around a large central corallite. Some of these are fully two lines long, and a third of a line broad. In the neighbourhood of these radiate groups, the surface is more or less vermicular in external aspect. The tabulæ are close, and about a seventh of a line apart. I have several specimens of this species in my cabinet, in which the structure is so coarsely granular that I did regard it as a variety of *Pachypora Lindstrom.* When, however, carefully sectioned specimens are examined, the alveolitic type is clearly pronounced. In another specimen from the same locality there are occasionally seen minute intermural pores, or young corallites, which is the characteristic of both *Fustulapora* and *Chætetes.* The structural characters of *Alveolites,* however, largely predominates, and therefore we can only regard such forms as diverging species, and as varieties between *Favosites* on the one hand, and on the other the structural details, which are found in both the genera *Chætetedæ* and *Fustulaporidæ.*

It will thus be apparent that in this genus there are present structural details which clearly indicate divergent conditions, which with further development unites and merges into allied groups, and all showing clearly that there was an innate tendency in the living animal to variation, and that modification was more or less regulated by the surrounding conditions during life.

Genus. BEUMONTIA. (Edwards and Haime.)

The next group in an ascending series which has the nearest relation to the preceding is the genus *Beumontia* (E. and H.). As, however, I have not yet discovered that genus in any of the localities I have yet examined, I will simply recapitulate the description of the eminent authors, which may be found in the Palæontographical Society's *Transactions,* 1850.

Corallum forming a tall, lobate mass, corallites basaltiform, somewhat flexuous, and showing distinctly costal striæ under the epitheca. Calices very variable in size, the largest about three lines in diameter; tabulæ closely set, mostly horizontal, and very slightly convex—some incomplete and subvesicular.

In the absence of facile evidence, I can only shortly refer to the structural character as described in the above memoir:—(1) The corallites are found in lobate masses, and basaltiform; (2) the calices are of variable dimensions; (3) the tabulæ are closely set, mostly horizontal, and slightly convex; (4) and some are incomplete and subvesicular.

It will thus be apparent that genus *Beumontia* possesses characters which indicate an intermediate group between *Alveolites* on the one hand and the genus *Michelini* on the other. It agrees with the former in the possession of more or less horizontal tabulæ, and with the latter by the fact that a portion of the tabulæ are irregular, and present a subvesicular aspect, and the necessarily variable aspect in their size in a transverse section; and thus may be said to merge from the former into that of the latter, and thus indicate that variability is innate, and that modification bridges and unites the former with that of the latter. There is, however, no mention made of mural pores. If mural pores are wanting, then the genus may be said to have an intermediate position between the *Tubulosa* and the simple forms of *Amplexus;* these supposed relationships must wait for more direct evidence.

Genus Michelini. (Köninck.)

Plate IV., Figs. 6 and 6a.

Generic Characters.—Corallum compound, and composed of closely-aggregated polygonal offsets from the lateral margins of the central tubular corallites, which are cylindrical when free from lateral pressure; when affected by lateral pressure they are prismatic. Gemmation caliculæ, and first observed as a minute semicircular plate at the angle of the parent corallite, which, with increased growth, enlarges across the angle of the primary corallite, and grows side by side, and all are encircled by the epitheca, and the external aspect is more or less radiciform. The calices are mammillated around their inner margins, pentagonal and hexagonal, in the large compound masses where they are more or less affected by lateral pressure. The walls are perforated by irregular mural pores. It seems to have been attached to foreign bodies by a single corallite. Some forms are in dome-formed masses, whilst other forms are in irregular pyriform and hemispherical masses. The tabula is more or less convex, and some are incomplete and subvesicular.

As regards the affinity and classificatory position of the genus *Michelini*, from the above account of the structure, there is little doubt that the genus forms an intermediate position between the genus *Beumontia* and the genus *Favosites*. With *Beumontia* it agrees in being in compound polygonal communities, and the

tabulæ are horizontal and slightly convex. Some are incomplete and subvesicular, and, in this respect, may be said to form an intermediate group between the compound vesicular forms and the simple forms of *Calophyllum* (Dana). I am, however, induced to believe that other forms will yet be discovered, which, with increased development of the vesicular zone, will more closely unite those genera; and with *Favosites*, it agrees in its mode of vesicular gemmation, and it being in compound communities in the possession of sparse tabulæ, and by its irregular mural pores. We have thus further indicated that new and more highly-organized forms merge from the simpler and less complex forms by successive stages of development—thus investing each successive stage of our inquiry with increasing interest, and inducing us to believe that other and more highly-organized forms wait our investigations.

From what has been stated, we are instinctively led to inquire into the structural details and classificatory value of, and as indicated in the only species of *Favosites* that I have met with in the carboniferous system.

Genus FAVOSITES. (Lamarck.)

Generic Characters.—Corallum in more or less spherical compound communities, and composed of irregular polygonal corallites, and extend outwards at right angles to the central corallites. The calices are varied in their form and size—some are pentagonal, whilst others are hexagonal, and they surround the spheroidal mass. The walls are perforated with irregular mural pores. Their development arises from the inner margin, and near the apex of the calice, and are first seen as a slight thickening of the wall, but, on further development, become an elongated depression, and gradually become subspherical in outline, when, with lateral pressure, they become more or less polygonal. There are minute spine-like processes or pseudo-septa (?) irregularly developed. If these spine processes are septa, they thus foreshadow the septal system of more highly-organized forms.

Favosites parasitica. (Phillips.)

Plate IV., Figs. 4 and 4A.

Specific Characters.—Corallum compound, and usually found encircling the spines of *Productus* in globular masses. The walls

are delicate, and fused with each other, which can only be observed in sections that are prepared for microscopical examination. The calices are unequal in size; some are very small, and seen at the angles of the larger corallites. Gemmation begins in the inner margin of the lip, which is first observed as a slight thickening of the wall, which, with further development, becomes subsemicircular, and merges into the polygonal aspect of the parent corallite. There is an epitheca; but, in consequence of the spherical character of the mass, and their union with each other, I am unable to define its character. The tabulæ are sparse, and extend from wall to wall. There are irregular mural pores.

Form and Size of Corallum.—Some forms are obovate, whilst others are spherical, and varying in size from a line to half-an-inch in diameter.

Formation.—Lower carboniferous.

Locality.—Howwood, Renfrewshire; and Brockley, near Lesmahagow, Lanarkshire.

This, the only species of this genus known as belonging to the carboniferous system, was described by Professor Phillips (Geol. of York, 1836), as *Calamapora parasitica* for a globular form found encrusting the stems of encrinites. M'Coy (*Syn. Carb. Foss.* of Ireland, 1844), was persuaded that it was more closely allied to the genus *Favosites*, and therefore described it as *Favosites parasitica*—a classification subsequently adopted by Edwards and Haime (Tran. Pal. Soc., 1850).

The genus *Favosites*, in some respects, is closely allied to the genus *Michelini* of Köninck (Plate IV., Figs. 6 and 6A) in the possession of irregular tabulæ. It is, however, separated from *Michelini* by its globular form, by its mode of gemmation, and by the fact that the corallites radiate out from the central parent corallite in all directions, and are therefore more or less at right angles to the centre of the community. While it possesses structural characters on the other side which foreshadow, and more or less unites it to the genus *Fistulipora* (M'Coy), it, however, differs from *Fistulipora* by the fact that the tabulæ are never so abundantly developed, and the parent corallite is never surrounded by minute pores, as is always found in *Fistulipora*. With our present knowledge, the genus *Favosites* may be said to be an intermediate group between *Michelini* on the one hand, and *Fistulipora* on the other, and will thus form a more or less connected series. Yet, I am persuaded that other forms will be

discovered that will more closely unite those groups, and more fully demonstrate the great principle that modification in the structural characters has been evolved by transitions of microscopic proportions.

The genus *Fistulipora* now falls to be considered in an ascending series.

Genus FISTULIPORA. (M'Coy.)

Generic Characters.—Corallum compound, and composed of minute cylindrical corallites, which are more or less surrounded by a system of circular cells half the diameter of the central corallite. These cells alternate with the cells of the neighbouring corallites in one form, while in another there are three cells between each corallite. The tabulæ are at right angles to the vertical plane of the corallites, and also the surrounding cells, and separated by spaces equal to the diameter of each. They are developed either as encrusting sheets or parasitic, and not infrequently they are found encircling the spines of *Productus* (Plate IV., Fig. 5).

The genus *Fistulipora* agrees with *Favosites* in being developed in compound encrusting communities, and there is always tabulæ present. It, however, has a divergent character, and is separated by the position of a system of cells, which encircles the larger corallites. In *Favosites* there are occasionally developed minute cells at the angles of the larger corallites, and thus indicate, with further development, the cellular tissue that always surrounds the larger corallites in *Fistulipora.* The latter character indicates a transitional condition which merge and more or less unite *Fistulipora* to groups which include, amongst others, the genus *Monticulipora* (Köninck), and which diverges and unites the genera *Palæces, Chætetes,* and *Diastipora*—a group which requires more careful consideration than has yet been devoted to them before they can be satisfactorily assigned their proper classificatory positions. I may, however, say in a general way that I do possess a large and varied series of each genus. While I am not disposed, in the absence of an examination of the type forms, to approach a description of their generic characters, yet, from the evidence in my possession, I am persuaded that, when carefully investigated, there will be found a series of divergent conditions that will unite the different genera into a more or less connected series, and amply demonstrate that there was an innate tendency to differentiation

in the tissue of the living animals, and that their morphological conditions were more or less affected by further development and the surrounding conditions.

At page 42, when describing the genus *Protocyathophyllum*, I stated that the simple forms of that genus had a close alliance to the genus *Amplexus*, of Sowerby, by the fact that they are always simple and free and developed from ova, and that in some forms the septal system was rudimentary, and rested upon the superior face of the tabulæ. I will therefore describe the generic character of the genus *Amplexus*, and point out what structural details indicate that development had been progressive, and wherein each species does indicate a correlation to each other.

Genus Amplexus. (Sowerby.)*

Generic Characters.—Corallum simple, cylindrical, sub-cylindrical, and tapering towards the base, is frequently tall, and more or less twisted. The epitheca is of variable stoutness, and there are encircling lines of growth and accretion ridges. The septa are either wanting, or are delicate and short, and of one order. The tabula are well developed, extending completely across the visceral chamber, and invariably exposed over a wide central area, into which they do not extend for any great distance. A rudimentary septal fossula is present, which is usually formed by a slight lateral depression of the tabulæ. The calice is circular and shallow, with a thin margin.

The genus *Amplexus* was established for the reception of a group of corals which form a natural and intermediate series between the compound tabulata as the tabulate species of *Aulopora*, and the dense and massive communities of the genus *Alveolites*, on the one hand, and to the genus *Calophyllum* on the other, and which can be traced by transitional varieties to pass into the genus *Zaphrentis*.

The nearest ally of *Amplexus* has usually been assumed to be the genus *Zaphrentis* of Rafinesque and Clifford, and there is doubtless a close alliance between the two. Typical examples of the former, however, are always readily and completely separated from characteristic species of the latter genus by the much more rudimentary conditions of the septal system and the nature of the

* Sowerby's Mineral Conchology, vol. I., p. 165.

septal fossula. Upon the whole, therefore, those two genera are distinguished from each other by characters of greater distinction than those which separate *Alveolites* from *Amplexus*. In order that the relationship of *Amplexus* to its near allies may be clearly defined, I will briefly refer to those genera which form natural and connecting links, as exhibited in their structural details in an ascending series. Before doing so, it will be necessary to point out a few of the more important specific characters of the genus *Amplexus*.

Amplexus minutus. (Thomson.) Sp. nov.

Plate III., Fig. 11.

Specific Characters.—Corallum simple, cylindrical, and minute. The epitheca is stout, and there are indications of minute annulations of growth. The calice is circular and deep in proportion to the size of the corallum. Septa wanting. The tabulæ are complete, and extend from wall to wall; there are twenty tabula in a corallum one line long.

Height of corallum, 1 line; diameter of calice, $\frac{1}{10}$ of a line.

Formation.—Lower carboniferous.

Locality.—Asheyburn, near Muirkirk, Ayrshire.

For a number of years I regarded this delicate species as belonging to the *Diatomaceæ* before deciding as to its proper classificatory position. I submitted it to one of our ablest authors in that department. He could find no trace of its alliance to the diatoms, and considered that its proper classificatory position was with the *Hydroids*, and have, therefore, from it being a simple tabulate form, placed it in the genus *Amplexus*, and believes that it connects the minute species of *Alveolites* with the genus *Amplexus*, and thus forms an important factor in tracing the development and transitional tendencies of the class. In order that we may more fully trace in the structural details the transitional characters indicated in the genus, I will simply refer to a few of the species, and show in what aspect their development is indicated, and wherein these transitional forms unite not only the species of that genus, but show how they merge into their nearest allies.

Amplexus Sowerbyi. (Phillips.)

Plate V., Figs. 1 and 1A.

The corallum is simple, the tabula distant, the wall is stout, and the septa are indicated by minute pointed granules.

Amplexus serpuloides. (Köninck.)

Plate V., Figs. 2 and 2A.

The corallum is simple, the tabulæ are numerous, the wall is thin, and the septa extend inwards. They are double the length of the former species, as minute spines, or about $\frac{1}{3}$ of a line.

Amplexus nodulosus. (Phillips.)

Plate V., Figs. 3, 3A, 4, and 4A.

The corallum is simple. The tabulæ are more or less convex, and curve at their lateral margins. The wall is delicate, and the epitheca is marked with delicate annulations of growth, and there are irregular nodular prolongations, which are more numerous near the inferior extremity. The septa extend inwards in fig. 3 for a line, and in fig. 4 for two-thirds of a line, and there are faint indications of interseptal dissepiments.

Amplexus spinosus. (Köninck.)

Plate V., Figs. 5 and 5A.

The corallum is simple, and the tabula is slightly more curved; and there is a series of sharp spines extending from the epitheca. The septa are slightly more numerous, and the interseptal dissepiments are considerably more increased in number.

Amplexus coralloides. (Sowerby.)

Plate V., Figs. 6 and 6A.

The corallum is simple, tall, and curved; the tabulæ are wide apart, and at their lateral margins sharply deflected downwards. The septa are longer than any of the preceding species, and are united by one interseptal dissepiment; and the fossula is indicated by a slight depression of the lateral margins of the tabulæ.

Amplexus irregularis. (Thomson.)

Plate V., Figs. 7 and 7A.

The corallum is simple, cylindro-conical, and tall. The epitheca is thin, and marked with longitudinal ribs, shallow annulations,

and crenulate encircling lines of growth. The septa are longer, and the interseptal dissepiments are more numerous than in any of the preceding species; and in the spaces usually occupied with the secondary septa there are very minute granules exposed on the inner face of the epitheca. The fossula is indistinct—one of the septa of shorter length extends into it.

Amplexus cornuformis. (Ludwig.)

Plate V., Figs. 12 and 12A.

The corallum is simple. The tabulæ are concave and deflected downwards at their lateral margins. The septa are stouter and longer, and the fossula is more pronounced.

Amplexus Haimeanus. (Köninck.)

Plate V., Figs. 8 and 8A.

The corallum is simple, short, and turbinate, and there are a few nodes irregularly over its surface. The septa are more developed than in any of the former species; and the interseptal dissepiments are more numerous. Plate V., Figs. 9 and 9A—another specimen of the same, showing the septa longer and the interseptal dissepiments more numerous.

Amplexus Henslowi. (Edwards and Haime.)

Plate V., Figs. 10 and 10A.

The corallum is simple, the wall is stout. The septa extend considerably further inwards than in the former, and united by interseptal dissepiments; and the tabulæ are irregular, and deflected downwards at their lateral margins.

Amplexus intermedius. (Thomson.) Sp. nov.

Plate V., Figs. 18 and 18A.

The corallum is simple, cornute. The septa extend inwards to near the centre of the central area, and in this respect is closely united the genus *Densyphyllum Dibowskei.* The interseptal dissepiments are more numerous than in any of the former species,

and the tabulate area is small, and only occupies about two-thirds of a line.

Amplexus variabilis. (Thomson.) Sp. nov.

Plate V., Figs. 20 and 20A.

Corallum simple, cornute. The septa are of variable length; some of them extend to near the centre of the central area, and each is united by numerous interseptal dissepiments.

It will thus be apparent that the genus *Amplexus* must be regarded as a very distinct one, and that in tracing the structural details of the group, it is patent that the modifications are of a very marked character, and may be followed throughout—from the minute simple tabulate species *Amp. minutus*, in which there is no septal system developed through all the stages of increased septal extension up to *Amp. intermedia;* in which the septa extend inwards along the superior face of the tabulæ, until they all but unite in the centre of the calicular cavity. In *Amp. intermedius* there are indications of secondary septa in the presence of minute granules, occupying the spaces in which the secondary septa are always developed; and thus indicate transitional characters which may be regarded as foreshadowing the more highly-organized genus *Calophyllum* of Dana, in which the secondary septa are more or less rudimentary—which is one of the distinguishing characters of that genus. There are modifications in the tabulæ equally distinct; and each species varies in other parts of the corallum, but it is only in the central area that any important distinction can be relied on for specific diagnosis; and therefore, the structural details, as indicated by gradations so minute, are of great importance to the practical palæontologist. But such delicate modifications are also extremely interesting, and so fully illustrate the potent principle that variability is not only innate, but is of great value for diagnostic purposes.

As has been formerly stated, the classificatory position of the genus *Amplexus* unites the genus *Alveolites* on the one hand, and passes, by gradations of extreme minuteness, into the genus *Calophyllum.* There are, however, these differences to be noted: the genus *Alveolites* is always in compound colonies, gemmation is by fissiparity, and there are always mural pores, and the tabulæ extend across the corallum from wall to wall.

In the genus *Amplexus* the corallum is simple, and developed

from ova; the tabula extends and is rectangular in some of the forms, whilst in those in which the divergent tendency is indicated they are either convex or concave. The septa are wanting in *Amp. minutus*, and more or less developed in all the other species, and in proportion as their transitional character is pronounced, there is a proportionate increase in the development of the septal system; and in one species, *Amp. irregularis*, the secondary septa are foreshadowed by minute granules occupying the space in which the secondary septa are developed.

In the genus *Calophyllum* the corallum is simple, and developed from ova. The tabulæ are irregular, and there are introduced vesicular tissues in the peripheral zone; and secondary septa are in some forms rudimentary, and in others more or less developed, and each is united by sparse interseptal dissepiments. It will thus be apparent that the latent principle of variability is abundantly exemplified, and that development from the simpler species to the more complex varieties is in no group better exemplified than in those under consideration; and in order that their connection and transitional characters may be clearly traced, I will now briefly notice the varieties of the genus *Calophyllum* of Dana.

In the preceding groups I have attempted to trace their generic relations and transitionary tendencies to variation, and in which we found in each successive genus distinct and easily separable structural details. We, however, now have come to a group in which the details are equally well specialized, but in which there are structural characters, which, although foreshadowing and occupying the position of secondary septa, as in *Amplexus irregularis*, yet, in no instance have we found secondary septa sufficiently developed to warrant us in doing more than to indicate and refer to their relative position as presented in the granular tissue that is more or less developed around the inner face of the periphery in that species. Where secondary septa are developed in more highly-organized forms, such rudimentary or atrophied organs are not only of high physiological importance, but their development is of much value in classification.

Although the secondary septa are introduced, and rudimentary in the next group which, in ascending series, falls to be considered, I do not wish it to be understood that the mere physiological importance of that organ exclusively determines its classificatory value, as in many of the succeeding groups which fall to be considered, the secondary septa are more or less developed, yet their

classificatory position is widely different. Practically, in tracing the development and divergent characters of this group of organic remains, the introduction of the secondary septal system can only be regarded as indicating their progressive development, and which, I believe, warranted Prof. Dana in assigning to them a clear generic position, whose relationship is indicated in the more highly-developed species of *Amplexus*. These have, on the other side, an intimate relation to the genus *Zaphrentis*, and in those forms in which the structural details are more fully pronounced they merge into and become united to the genus *Campophyllum* (if that generic name can be longer retained). This, however, I have grave doubts of, if we are to retain such species as *Cyathophyllum Wrighti*, *Cyath. paracida*, and others, as belonging to the genus *Cyathophyllum*, which will fall to be referred to by and by. Meanwhile, I will briefly refer to the genus *Calophyllum Dana*, and see wherein the structural characters of that genus warrants us in believing that development was progressive, and if indicated, how, and by what means, can their more highly-organized details be traced.

Genus Calophyllum. (Dana.)

Generic Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is well developed, and usually stout, and there are encircling lines and annulations of growth. The calice is circular and shallow. The septa are of two orders, and of variable length. The secondary are rudimentary, and interseptal dissepiments are indicated in some forms, and there is a proportional increase in those species in which the primary septa are more fully developed. A septal fossula is present, and usually one septum, half the length of the others, extends into it. The circumferential zone of vesicular tissue is indicated, and the septa rests upon the superior face of the broad tabulæ.

The genus *Calophyllum* was established by Prof. Dana for the reception of a group of simple tabulate forms, which go to form a natural and intermediate series between the genus *Amplexus* and that of the genus *Zaphrentis*, and the more highly-developed forms merge so closely to the genus *Campophyllum* (Edwards and Haime), that it becomes doubtful whether the more highly-developed species of the former can be regarded as having more than specific distinction from the latter. If, however, the genus *Calophyllum* is

retained—and there seems to me no reasonable doubt regarding its classificatory position and value, indeed, a *priori* establishes its validity—then the question arises, To what classificatory position can we assign the genus *Campophyllum?* As that genus falls to be considered further on, I will meanwhile note a few of the structural characters of the genus *Calophyllum*, and see whether there are indicated structural details in the group that will warrant us in regarding their transitional characters indicative of progressive development.

Calophyllum. Sp. ?

Plate V., Figs. 15 and 15A.

Specific Characters.—Corallum cylindro-conical, and tapering to a point. The calice is circular and shallow, and the centre of its floor is occupied with broad flat tabula. The primary septa extend inwards fully a line, the secondary septa are rudimentary, and represented by minute spines, which are stout at their base, and become pointed, and each rests upon the tabula. The epitheca is stout, and there are broad and shallow annulations of growth. The tabulæ are extremely varied, and bend downwards to the dorsal side of the corallum, and the vesicular tissue is indicated. The septal fossula is obscure, and two of the primary septa, of shorter length, extends into it. There are thirty-two primary, and an equal number of minute secondary septa.

Height of corallum, 1 inch; diameter of calice, 7½ lines.

Formation.—Lower carboniferous.

Locality.—Found at Auchenskeoch, Dalry, Ayrshire.

In the absence of accurate knowledge as to the specific character of the type of the genus, I have not added specific names to the group. There is, however, one exception—*i.e.*, *Calop. Danai.*

This species is readily distinguished by the broad tabulæ—the primary septa being short—and by the minute secondary septa and the much greater curvature of the tabulæ, and forms a natural and intermediate species between *Amplexus* and *Calophyllum.* The presence of the abortive secondary septa clearly indicates its generic position.

Calophyllum. Sp. ?

Plate V., Figs. 16 and 16A.

Specific Characters.—Corallum simple, cylindrical, and curved. The calice is circular and moderately deep, and the septa extends

[illegible] a third of the total width of the corallum, and rest upon the superior face of the tabulæ. The septa are of two orders. There are twenty-four primary, and an equal number of smaller secondary septa, and each is united by sparse interseptal dissepiments. The fossula is large, and like all the primary septa, a third of the length of the latter extends into it. The central area is a flat shallow depression about a third of the total width of the corallum. In the longitudinal section Fig. 11a, the tabula are seen to extend from wall to wall, and to bend downwards to the central axis of the corallum. The vesicular tissue is sparse and large, and extends from the wall inwards, and rests upon the superior face of the tabulæ.

Height of corallum, 1 inch 3 lines; diameter of calice, 6 lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

This species differs from the former by the stoutness of its wall.

Caninophyllum. Nov.

Plate V. Figs. 11 and 11a.

Specific Character.—Corallum simple, cylindro-conical, and curved. The epitheca is stout and marked with encircling lines and deep broad annulations of growth. The calice is moderately deep, and its centre is occupied by flat tabulæ, which is to a large extent concealed by the long septa. The septa are of two orders; the primary extend inwards a little over a third of the total width of the corallum. The secondary are represented by sharply-pointed granules, and each is united by interseptal dissepiments. The fossula is indistinct. In the longitudinal section (Fig. 11a) the tabula are more or less horizontal. The vesicular tissue is convex, extends inwards, and rests upon the superior face of the tabulæ.

Height of corallum, 1 inch 3 lines; diameter of calice, 6 lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

This species differs from the former by the stoutness of its wall.

The secondary septa are short, broad at their base, and pointed at their apex; or, in other words, are pointed granules.

Calophyllum Danai. (Thomson.) Sp. nov.

Plate V., Figs. 19, 19A, and 19B.

Specific Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is thin and marked with longitudinal ridges and irregular annulations of growth. The calice is moderately deep, and a plate is seen extending across the superior face of the tabulæ. The septa are of two orders. The primary septa extend fully a third of the total width of the corallum, and the secondary are minute and hardly recognizable. They bend at their inner ends, and become attached to the primary septa, and each is united by rectangular interseptal dissepiments. The longitudinal section (Fig. 19B), exhibits the circumscribed tabula, which is rendered more or less disconnected by the position of the plate that is seen to extend across the floor of the calicular fossa in the transverse section. The fossula is large, and one of the primary septa, of shorter length, extends into it; and the two neighbouring septa are seen to coalesce at their inner ends, to become united and attached to the central plate, and to extend over the tabulæ.

Height of corallum, 1 inch 6 lines; diameter of calice, 3 lines.

Formation.—Lower carboniferous.

Locality.—Found in Charleston Quarry, in the shale that overlies the thick beds of limestone, where it is somewhat plentiful.

This species is readily distinguished from all the other species of the genus, and by the possession of characters of an unusually distinct kind. The central plate that extends across the superior face of the tabulæ indicates the transitional tendency to variation and modification, and I believe that other forms will yet be discovered that will still more closely unite the entire series. It affords me no mean pleasure to dedicate it in honour of Professor James Dana, the eminent American naturalist, the discoverer of the genus.

Calophyllum. Sp. ?

Plate V., Figs. 17 and 17A.

Specific Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is thin, and there are broad and shallow

annulations of growth. The septa are of two orders. The primary extend inwards to near the centre of the calicular cavity, one of them extends partially across the centre of the central area, and there is one that extends across and becomes united to a septum on the opposite side, and all rests upon the superior face of the tabulæ. The secondary septa are minute, and all are united by interseptal dissepiments, which are more or less angular. The fossula is large, and extends inwards to near the centre of the central area, and the two septa that forms its lateral walls bend at their inner ends, and become united; and one of the primary septa, of shorter length, passes inwards for two-thirds of its length.

Height of corallum, 1 inch 6 lines; diameter of calice, 7 lines.

Formation.—Lower carboniferous.

Locality.—Found in Roughwood, Beith, Ayrshire.

This species exhibits structural details of an unusually marked character, in the greater extension of the primary septa inwards towards the centre of the central area, and by the union of the two septa that forms the lateral walls of the fossula, which is one of the distinguishing characters of the genus *Zaphrentis*—characters which did induce me to place this species as belonging to that genus. Indeed, it was only after tracing the transitional characters of the group, that I was induced to place it amongst the varieties of *Calophyllum*, and which indicates, in a marked manner, that in this genus the tendency to variation is well demonstrated.

Calophyllum. Sp. ?

Plate V., Figs. 14 and 14A.

Specific Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is stout, and there are broad and shallow annulations of growth. The calice is shallow, and exposes a broad flat floor. The septa are of two orders, and irregular in their length. The primary extent inwards for fully a line in length. The secondary are minute, stout at their base, and pointed near the apex, and united by sparse interseptal dissepiments. The fossula is indistinct. The longitudinal section exposed the sparse broad tabulæ, and the vesicular tissue in the peripheral zone is indicated. This species and *Calophyllum*, Fig. 16A, are both deeply concave at the inferior extremity of the corallum, and broad, indicating that the ova had become attached to a convex body, and that the soft plastic ovum had folded over,

and conformed the basal extremity in accordance with the outline of the body it was attached to, and clearly exemplifying that variation was more or less induced by external conditions.

Height of corallum, 2 inches; diameter of calice, 10 lines.

Formation.—Lower carboniferous.

Locality.—Found at Roughwood, Beith, Ayrshire.

This species approximates closely to *Calophyllum* (Fig. 15), its nearest ally. It, however, differs in the greater development of the septal system, and the interseptal dissepiments are more fully represented, and in the greater horizontality of the tabulæ. Upon the whole, it is readily distinguished from all the preceding species, and possesses characters which are nearly related to the genus *Campophyllum Murchisoni*, Edwards and Haime (Plate IX., Fig. 9). Indeed, so closely do this species approach to the latter, that I regarded it as a young specimen of the former. When, however, I began to trace the generic relations of the series to illustrate my address, I found that it was one of a group whose development could be traced as merging by infinitesimal gradations, and indicated that in the genus *Calophyllum* there are forms which merge so closely to the genus *Campophyllum* on the one hand, and to the genus *Zaphrentis* on the other, that it becomes difficult to define their separate and distinct relationships. Indeed, that can only be done by the examination of a large and more or less connected series, which induces me to assert that we have in these transitional forms illustrated clearly that there are no aberrant groups, that they are all more or less liable to modification, and that in this genus the structural characters are seen to diverge in all directions. And from the fact that in some of the species the secondary septa are represented by pointed granules, which induces me to regard such as a further development of the granular tissue found in *Amplexus irregularis*, and occupying the position of the septa in more highly-organized forms, and which may be traced merging from simple granules, which, with further development, become pointed, and in other forms may be traced extending inwards in varied lengths, and believe that such transitional tendencies indicate plainly that modification and development is universally stamped upon this great division of the fauna of the carboniferous system. It is true of this as of all the other groups, there are intermediate forms wanting—I believe not absent in nature, but from our limited knowledge of the fauna and stratigraphical conditions of the carboniferous system, they have not yet been discovered. But if those

interested, and if others who—instead of loading the literature of the science with crude and ill-digested descriptions of fragmentary species, which lead to endless confusion and blocks the onward wave of investigation—would only lend their aid, we would soon perceive that, instead of a fragment here and a species there, the great scheme of creation would be better understood, and thus weld and unite the scattered links of the chain that binds and unites the simpler forms to the more complex and more highly-differentiated groups, and thus aid in illustrating that there has been an innate tendency to modification in every created form.

The near relation and transitional tendency in the genus *Calophyllum* to merge into and to unite in the simpler species of *Zaphrentis*, implies our consideration of the development of that genus. I may, however, state that the few species selected for my illustrations are not to be regarded as an exhaustive series. They represent centres pronounced in their character. Many other illustrations could have been added, which would have more fully illustrated the true character of the genus.

Genus Zaphrentis. (Rafinesque and Clifford.)

Generic Characters.—Corallum simple, turbinate, conical, and cylindro-conical, and more or less curved. The calice is deep, with a large and conspicuous fossula, and formed by the coalesence of a portion of the septa, which at their inner ends fold round and form its walls. The septa are lamellar, and are well developed, extending in some forms to the centre, while in others a portion of them stop short. They then coalesce and become united, and converge to the centre of the visceral chamber; whilst in the simple and passage forms of *Zaphrentis* and the more highly-developed forms of *Calophyllum* the septa do not reach the centre of the visceral chamber. The tabulæ are conspicuous and variable, and the septa are more or less prolonged over their superior surface. The interseptal loculæ are filled up towards the outer margins of the corallum by remote convex dissepiments, and the tabulæ fall short of the circumference of the corallum, and rest upon the interseptal dissepiments, and generally have a downward curvature near the circumference; and this is usually more apparent in the ventral side of the corallum. The general form of *Zaphrentis* is variable. Some are turbinate, and attain a moderately large size, whilst others are very small. The epitheca

is variable; in some species it is stout, whilst in others it is thin, and is usually marked with accretion ridges and fine encircling lines of growth. The calice is deep, and its upper margin thin, and there is always a deep fossula. The most characteristic feature of the fossula, however, is the fact that it is formed by the coalescence of a greater or less number of the septa, which unite at their inner ends, fold round, and form its walls.

Upon the whole, the genus *Zaphrentis*, as illustrated by the specimens found in Scotland, may be readily recognized by the complete, or comparatively complete, development of the tabulata system. The irregular development of the tabulæ, as presented in the longitudinal sections, and the existence of a large and conspicuous fossula, and the septa fold round and form its walls, and may be therefore regarded as an intermediate group between *Amplexus* on the one hand and *Calophyllum Danai* on the other. And the more dense varieties have a close relation to the genus *Densiphyllum Dybowskei*, and in certain of the varieties there is indicated a central cellular tissue, which is the distinguishing character of the genus *Centrecelulosum*. It is separated from *Amplexus* by the greater development of the septal system. In the latter there are no secondary septa, and the primary septa extends for a limited extent into the visceral chamber, and are usually of greatly shorter length; and the rudimentary development of the interseptal dissepiments in the more complete forms, and the greater development of the tabulæ, which extend from side to side across the entire width of the corallum; and from *Calophyllum*, from the fact that in the latter the septa never extend into the centre of the central area, and the fossula is never so largely developed, and in only one species of the latter do the septa forming the lateral walls of the fossula indicate union at the inner boundary; and from *Densiphyllum*, from the fact that in the latter the septa always converge, and unite in the centre of the visceral cavity, and the interseptal dissepiments are numerously represented. It will thus be apparent that the genus *Zaphrentis* forms a distinct central group, in which there are species which diverge from and merge into forms which are more or less remotely connected, and clearly illustrates the principle that differentiation is innate, and that development and transitional relations are universal. I shall now briefly refer to structural characteristics of the group for fuller details. I beg to refer to the *Proceedings* of the Society for 1881.

Zaphrentis intermedia. (Köninck.)

Plate VI. Figs. 1 and 1a.

The calice is deep, and the septa stops short of the centre of the visceral chamber. The fossula is large, and the septa do not fold round at their inner margins, and form its walls. It will thus be apparent that in this species we have a passage form, which possess characters that may be said to be transitional between the genus *Amplexus* on the one hand, by the fact that the septa stop short of the centre, and exposes a large tabulate area in the centre of its floor; and on the other hand it is closely related to the genus *Calophyllum*, in the possession of minute secondary septa, and the septal fossula is more pronounced than is usually found in *Amplexus*. It, however, possessed characters sufficiently zaphrentoidal to warrant the eminent author to regard it as an intermediate form.

Zaphrentis cyathina. (Köninck.)

Plate VI., Figs. 2 and 2a.

The calice is circular, and moderately deep. The septa are of two orders, and lamellar, and converge inwards, and on the latro-ventral side they gently fold round the inner end of the fossula, and form its walls. In this form there is a further extension of its septa inwards, and the slight bending inwards to the wall of the fossula indicate that the zaphrental characters are more pronounced.

Zaphrentis amphitheca. (Thomson.)

Plate VI., Figs. 5 and 5a.

The calice is circular, and moderately deep. The septa are lamellar, and at their inner ends the lamellæ curve round the inner ends of the interseptal spaces, and bend inwards and form the lamellæ of the neighbouring septum, representing a series of deep convolutions; and the interlamellar spaces are open at their outer extremities, leaving an open free communication with the interthecal space, and presenting the form of a double wall.

This remarkable species differs so widely from all the other species of the genus, in the possession of the double wall and the

vertical plates in the interthecal space, that I did regard it as possessing characters of generic distinction; but the deep fossula, and the fact that the inner ends of the septa fold round and form its walls, as in *Zaphrentis* proper—which I believe to be the character of primary importance in the definition of the genus *Zaphrentis*—allied it so closely that I was induced to abandon the creation of a new genus for it and allied forms; and therefore I regarded the double wall as only sufficiently distinct for the specific name, and think it may be regarded as a transitional passage from this into a group which, with further discoveries, may form an interesting connection between the genus *Zaphrentis* and a genus yet to be established.

Zaphrentis Edwardsiana. (Köninck.)

Plate VI., Fig. 9.

Represents a transverse section of a large specimen of this species in which the calice is circular and shallow. The septa are of two orders, and lamellar, short on the dorsal side of the corallum, and extend inward for two lines over the upper face of the tabula, and on the ventral side they extend into the centre, coalesce, and form the walls of the fossula. The secondary septa are short, and not more than a third of a line in length, and the interseptal dissepiments are few in number, thus presenting characters of an extremely interesting nature, and exhibiting structural details which belong to the genus *Calophyllum*, in the possession of short primary septa on the dorsal side, and the minute secondary septa; while on the ventral side a portion of the septa extend inwards to the centre of the calicular cavity, and fold round and form the walls of the calicular fossula—the distinguishing character of *Zaphrentis*—and thus present dimorphic structural details, which clearly indicate the innate tendency to variation.

Zaphrentis Guerangeri. (Edwards and Haime.)

Plate VI., Fig. 13.

Represents a transverse section of a large specimen of this genus, in which it will be observed that the wall is very stout and the septa of two orders. The primary septa have a near relation to

the genus *Calophyllum* on the dorsal side and to *Zaphrentis* on the ventral side of the coralium, where a portion fold round and form the walls of the fossula, and the secondary septa are hardly recognizable. Thus, while there is a considerable extension inwards of the septal system, yet there is the dimorphic character pronounced, which indicates not only the transitional tendency of the group, but a more highly-developed system.

Zaphrentis Bowerbanki. (Edwards and Haime.)

Plate VI., Fig. 3.

In which the septal system is distinguished by the greater extension inwards, and a portion of them are united at their inner ends and on the ventral side; while a portion coalesce, fold round, and form the walls of the large fossula, indicating a further development of the structural details.

Zaphrentis spinulosa. (Edwards and Haime.)

Plate VI., Fig. 7.

Represents a transverse section, in which the septa do not reach the centre of the visceral chamber, and the centre is occupied with flat tabulæ. The septa are of two orders, and the secondary septa are in the form of minute denticles, and thus exhibit structural characters which have a close relation to the more highly-developed species of *Amplexus*.

Zaphrentis Griffithi. (Edwards and Haime).

Plate VI., Fig. 4.

In this species a large portion of the primary septa extends inwards to the centre of the central area, and the secondary septa are hardly recognizable. The fossula is large, and a portion of the septa coalesce and form its walls.

Zaphrentis Cliffordana. (Edwards and Haime.)

Plate VI., Fig. 15.

The septal system is more fully developed, and a larger proportion of them extends into the centre of the calicular fossa. The

fossula is large, and its zaphrental character is not so pronounced, and may be regarded as dimorphic, but in which the structural character appears in a greater proportion than it exhibits of the *Calophyllum* type. The latter structural details are all but obsolete, and in none of the forms represented do we further find any of the characteristics of the latter genus.

Zaphrentis centralis. (Edwards and Haime.)

Plate VI., Fig. 8.

Represents a transverse section, in which a portion of the septa unite in a fasciculate group, and at their inner ends they are united by delicate plates, which converge, and meet in the centre of the calicular cavity, and the fossula extend into the centre of the central area. In this species there is an increased extension inwards of the septal system, and its zaphrental characters are clearly pronounced.

Zaphrentis vermicularis. (Köninck.)

Plate VI., Fig. 14.

Represents a transverse section of an interesting small species, and may be regarded as aberrant in its structural characters. It is grouped by the eminent and accurate observer as belonging to the genus *Zaphrentis*, but, if carefully compared, it will be observed that it possesses characters which unite it with *Calophyllum Danai* (Plate V., Fig. 19) in the possession of three delicate plates, which extend across the central area. It differs, however, from the latter species by the fact that there are three central plates, while in *Calo. Danai* there is only one that extends across the face of the tabula, and thus clearly shows that, with further development and the innate tendency to transition, there is a constant and persistent tendency to variation.

Zaphrentis patula. (Michelin.)

Plate VI., Figs. 10, 12, and 12A.

Represents sections made at three different parts of the same corallum. Fig. 10 is a transverse section, taken from the base of

the calicular cavity, showing only the upper portions of the septa resting upon the tabulæ. Figs. 12 and 12A show their union with the tabulæ, and thus accounts for the structural differences that are apparent in the sections. In all the septal system is seen to extend inwards to the centre of the calicular fossa; and in Fig. 12 there is presented a more or less vesicular tissue, arising from the section passing through the base of the irregular tabulæ, and thus giving a somewhat vesicular aspect. The secondary septa are minute, and, on the whole, this species may be regarded as an excellent example of the genus *Zaphrentis.*

Zaphrentis Phillipsi. (Edwards and Haime.)

Plate VI., Fig. 16.

Represents a transverse section of a small species in which the septa is delicate, and converges into the centre, the fossula being large, and the interseptal dissepiments more numerous, and is altogether a typical example of the genus *Zaphrentis.*

Zaphrentis. (Sp.)?

Plate VI , Fig. 19.

Is a transverse section of a variety which has a near relation to *Zaph. echinatis* (of Thomson). It, however, differs from that species in the septal system being more fully developed, and they extend into the centre of the corallum, and the interseptal dissepiments are more fully developed. The septal fossula is large, and extends into the centre of the calicular cavity, and, on the whole, this species exhibits structural details more fully developed than is found in any of the preceding species, and may be regarded as an intermediate species between *Zaphrentis* on the one hand, and *Densiphyllum Dybowskei* on the other, and thus forms another of the transition varieties, which, with further development, become pronounced in their character.

Zaphrentis Omalinsi. (Edwards and Haime.)

Plate VI., Figs. 11 and 11A.

Fig. 11 represents a transverse section of a species in which the epitheca is stout, and the septal system converges to near the

centre of the corallum, and at their inner ends are united to a central cell. The septa are of two orders, and the secondary septa are minute and hardly recognisable. The fossula is large and extends inwards, and is bounded at its inner extremity by the central cell. Therefore, while the zaphrental characters are pronounced, yet the central cell indicates a transitional tendency into groups in which the central area is occupied by a system of cells, to which the septa are united at their inner ends, and therefore, with further development, is regarded to have generic distinction.

Zaphrentis tuberculata. (Thomson.)

Plate VI., Figs. 17 and 17A.

Represents another variety, in which the cellular tissue in the centre of the corallum is still more pronounced, and indicates that the structural details have now the dimorphic condition, and may be regarded as an intermediate species which, while the zaphrental characters are represented, yet the cellular tissue in the centre presents a passage condition, and thus have near relationships to *Zaphrentis* on the one side, and which, with further development, merges into another group, which will fall to be considered as a new genus to be designated *Centrocellulsum.*

While the typical species of *Zaphrentis* possesses characters which clearly separate the genus from all the other groups of the system, yet, from the structural details, as indicated in the species selected for my illustration, it will be apparent that amongst those forms that have been regarded by their eminent authors as possessing structural characters which warranted them to place them as belonging to the genus *Zaphrentis*, there are several which exhibit dimorphic tendencies, in which there are structural details that truly indicate transitional conditions, and which may be regarded as diverging in all directions, and may be summarized as follows:—

(1) *Zaphrentis intermedia*, by its more highly developed organization, indicates not only its relation to the genus *Amplexus*, but the transitional tendency from the latter into the zaphrental type, and has a close relation to the genus *Calophyllum* in the possession of minute secondary septa, and the fossula is more pronounced in its character than is found in *Amplexus*, and therefore it may be said to be more or less trimorphic in its character.

(2) Fig. 2—*Zaphrentis cyathina*—has the zaphrental type more fully developed, but indicates relationships with the genus *Calophyllum.*

(3) Fig. 9. *Zaph. Edwardsiana.* In this species the relationship to the genus *Calophyllum* is clearly indicated on the dorsal side of the corallum, by the presence of the short septa resting upon the superior face of the tabulæ, while on the ventral side the septa converge inwards to the centre, fold round, and form the walls of the calicular fossula, and is therefore dimorphic.

(4) Fig. 15—*Zaph. Cliffordini*—in which the septal system is more fully developed. The fossula is large. In this species, however, there is a relationship to the genus *Calophyllum*, although not so pronounced as in the preceding.

(5) Fig. 13. *Zaph. Guerangeri.* In this species there is a further development of the zaphrental characters on the ventral side, while the dorsal side of the corallum the calophylloid characters are represented, but less pronounced.

(6) Fig. 3. *Zaph. Bowerbanki.* The structural characters are more fully developed, and may be regarded as possessing the zaphrentoid type, and the relationship to the genus is pronounced.

(7) Figs. 4, 6, 10, 12, and 16. These species all represent the structural characters which clearly establish them as being central types of the genus *Zaphrentis.* There might have been sections of other species which I might have included, but hope these will suffice to illustrate what may be regarded as typical species of the genus; and from a careful comparison of these, with those forms in which there is indicated transitional conditions, there is a more or less pronounced relationship, which clearly show an innate tendency to variation.

(8) Fig. 14. *Zaph. vermicularis.* The principal structural characters of this little species are zaphrentoidal. In the central area, however, there are transverse plates which indicate not only a relationship to *Calophyllum Danai*, but also illustrate how universally the transitional tendency is innate. In *Calophyllum Danai* there is only one plate extending across the central area, while in this species there are three, which, with further development and modification, would merge into a distinct and separate group, for which a new genus would (and I believe will) be created for their reception.

(9) Fig. 8. *Zaph. centralis.* In this species there is represented many of the structural characters of the genus *Zaphrentis.* In

the central area, however, there are a series of delicate plates, which converge more or less to the centre of the central area, structural details which properly belong to more highly-organized genera, and may be regarded as foreshadowing, and with further development would merge into, and thus unite through this transitional species, those genera which Professor Agassiz regarded as belonging to the *Hydrozoa*, to those genera in which the lamellæ are largely developed, and which properly belong to the *Actinozoa*. Indeed, I again venture to assert that forms will yet be discovered in which the transitional characters will be clearly traced, and the relationships fully established.

(10) Fig. 5. *Zaph. amphitheca.* In this species there are characters of a remarkable kind. The zaphrentoidal type is somewhat pronounced. But there are other characters which clearly indicate a transitional tendency of a very marked nature, in the possession of the double wall, and the lamellæ of the septa folding round in opposite directions, a continuation of which form the lamella of the neighbouring septa—characters which, when our knowledge of these organic remains is more complete, will warrant palæontologists in removing this species from the genus *Zaphrentis*, and the creation of a new genus for the reception of this, and species yet to be discovered.

From the foregoing observations, I venture to say that in this genus there is indicated transitional characters of a marked nature. While the genus *Zaphrentis* possesses structural details that are very pronounced, and show clearly that as a genus it is separated, and may be readily distinguished from all the other genera of coralline remains found in the carboniferous system, yet from the transitional tendencies pointed out as belonging to a number of the species, we have clearly indicated in this genus that there are polymorphic characters that warrant us in assuming that development and transition is not only present but is of a varied description. And if I might be permitted to assert, the known in this group of organic remains leads us to realize how little we do know, and how much there is to be discovered before we can even approximately understand their true relationships.

There is a genus which is represented by one species—*i.e.*, *Cyathopsis cornu-bovis Michelini*—which calls for special consideration, not only from its isolation as a single form, but it possessing characters of an unusually distinct nature.

Cyathopsis cornu-bovis. (Mich.)

Plate V., Figs. 21 and 21A.

Generic Characters.—Corallum simple, cylindro-conical, and curved. The epitheca is stout, and marked with longitudinal lines and annulations of growth. The calice is moderately deep, and the floor is occupied with tabulæ, and there is a minute elongate plate in its centre. The septa are of two orders—the primary extend inwards to near the centre, and the secondary are hardly recognizable. The interseptal dissepiments are sparse; the septal fossula is indistinct.

This isolated specimen may be said to possess characters that point to relationships in two directions. The septal system is more nearly allied to the characteristic arrangement of the septa of *Calophyllum* than to any other genus that I am acquainted with, by the fact that their extension inwards is along the face of tabulæ, and there is no circumferential zone of interseptal dissepiments in the interseptal loculi. It, however, differs from that genus by the possession of the plate in the centre of the tabulæ —a characteristic which, although singular, yet may be regarded as a transitional form between the simple tabulate forms and those groups in which the columella is developed, and which has been regarded as of generic distinction. In the absence of other species, I merely desire to note its place and position, and with our present knowledge (provisionally) can only regard it as one of a series which forms a connecting link between the tabulate forms of *Calophyllum* and those genera in which the columellarian line is of generic importance, and thus forcibly illustrating the endemic tendency to variation, which, with further development, merge and unite genera of diverse characters.

The next group which falls to be considered is the genus *Campophyllum* (Edwards and Haime). When referring to the structural characters of the genus *Calophyllum Danai*, I pointed out that there was an intimate relation between the latter and the genus *Campophyllum* (Edwards and Haime), and that the genus *Calophyllum* was characterized by the fact that the septa extends uninterruptedly from the wall inwards, and stops short of the central area, and there was a porportionate increase or diminution in the exposure of the tabulæ in the floor of the calicular

fossa, in direct ratio with the increase or diminution of the septal system.

As regards the classificatory position of the genus *Campophyllum*, as formerly remarked, I had great doubts as to the propriety of retaining that genus as belonging to the fauna of the carboniferous system. Since I began the preparation of my address, I have carefully compared the structural characters of each of those genera, and have decided that the genus *Campophyllum* may be regarded as an intermediate group between the genus *Calophyllum* on the one hand, and the genus *Cyathophyllum* on the other, which will include a number of species that have been grouped in the genus *Cyathophyllum*. The latter genus, however, was established for the reception of a group whose septal system converged inwards to the centre of the corallum, and were bent at their inner ends, and formed a pseudo-columella, and therefore cannot include those forms in which the floor of the calice is exposed in a more or less broad tabulate area.

Genus *Campophyllum*. (Edwards and Haime.)

Generic Characters.—Corallum simple, and some forms merge into compound communities. Calice moderately deep. Tabulæ well developed, and extends over a large central area, and never reach the inner surface of the theca. Outside the tabulate area there is a zone of vesicular tissue, of varied extent. The septa are short, and never extend to the centre, and exposes the tabula in the broad median space. In the peripheral zone the interseptal loculi are occupied by a system of dissepiments. The septa are of two orders.

As I have formerly remarked, the genus *Campophyllum* may be regarded as intermediate between *Calophyllum* and the genus *Cyathophyllum*. In the genus *Calophyllum* the septal system converges from the theca more or less inwards, and there is no vesicular tissue around the peripheral zone, and the tabulæ are irregular and sparse, while in *Campophyllum* the tabulæ are more numerous. In *Campophyllum Murchisoni* (Edwards and Haime), Plate VII., Fig. 9, the interseptal loculi are occupied externally by fine dissepiments, which give rise to a peripheral zone of vesicular tissue, which is more or less dense in the different species, and in a longitudinal section are convex—convexity inwards, and pointing upwards—and arranged in oblique rows; and the septa never

extend to the centre of the calicular cavity. From the typical *Cyathophyllum*, again, the genus is separated by the much less highly-developed condition of the septa and the exposure of the tabulæ over a large central area.

As defined by Edwards and Haime, the genus *Campophyllum* contained only one species of a simple coral. If, however, we remove such species as *Cyathophyllum paracida* (M'Coy) from its present genus, and grouping it with *Campophyllum*, as suggested by M. Edwards and Haime (Pol. Foss. des Terr. Pal., p, 365), the reason for such a change is that the septa in this and allied species never reach the centre of the calicular fossa, but always leave a portion of the tabulæ exposed; whereas in the typical *Cyathophylla* the septa meet in the centre. In adopting this rearrangement, then, *Campophyllum* will contain compound as well as simple forms, and will thus merge and unite those forms which Agassiz regarded as belonging to the *Hydroids*, with the groups which are regarded as belonging to the *Zoantharia rugosa*. If these changes are accepted, and I see no valid reason why they should not, we will thus have presented to us a deep organic bond —a bond that is innate—which produces species not only like each other, but also varieties that are nearly alike, and those forms that are dissimilar indicate that modification is inherent, and is more or less affected by the surrounding physical conditions, and that variation is, to a considerable extent, influenced by the organisms being brought into new relationships.

In summarising the characteristic of the species, I will first describe the specific characters of the type of the genus, and afterwards briefly refer to the points in which the different species differ.

Campophyllum Murchisoni. (Edwards and Haime.)

Plate VII., Fig. 9.

Specific Characters.—Corallum simple, tall, cylindro-conical, and curved. The epitheca is thin, and marked with encircling lines and shallow annulations of growth. The calice is moderately deep, and its floor is occupied with broad flat tabulæ. The septa are of two orders. The primary extend inwards for $2\frac{1}{2}$ lines, and rest upon the tabulæ. The secondary septa are small, and each are delicate around the peripheral zone. They become stout and united by a stout circumferential band; they then become separated and

extend inwards, and are thin and pointed at their inner ends. Around the peripheral zone there is a system of vesicular tissue occupying the interseptal loculi, which, in a longitudinal section, are convex — convexity inwards, and pointing upwards — and arranged in oblique rows. The fossula is large, and formed by an elongated depression on the superior face of the tabulæ, and three primary septa, of shorter length than the others, extend into it.

Height of corallum, 7 inches; diameter of calice, 1 inch 3 lines.

Formation.—Lower carboniferous.

Locality.—Found at Durnish, County Limerick, Ireland. I have this species from Scottish strata, but have not yet got it engraved for publication.

Campophyllum. Sp. ?

Plate VII., Fig. 5.

Represents a species in which the septa are delicate, and the interseptal dissepiments are more numerous. The calice is bisected, and indicating the first appearance of fissiparous development by the presence of a septum on each side. At the bisected part of the corallum, extending considerably further inwards, there are several vesicles along the inside, each foreshadowing a continuation of the septa around each bisected corallum. The fossula is large, and indicated by a depression on the face of the tabula, and three of the primary septa, of shorter length than the others, extend into it. The tabulæ are numerous, and exposed in the floor of the broad flat median area, and rest upon the interseptal dissepiments.

Height of corallum, $1\frac{3}{4}$ inch.; diameter at the broadest part, 10 lines.

Figure 8 represents a young variety of the same species, in which the fissiparity is further developed, and in one of the corallites there is a central median plate, indicating the development of a columella.

Height of corallum, 1 inch; diameter, 4 lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Campophyllum cylindrica. (Scouler.)

Plate VII., Fig. 11.

In this species the septa are considerably more developed, and in two orders. The primary extend inwards for $6\frac{1}{2}$ lines on the

dorsal side, and 3½ lines on the ventral side of the corallum. The interseptal dissepiments are largely increased in number. The tabulæ are numerous, and rest upon the inner margin of the interseptal dissepiments. The calice is deep, and its floor is occupied by broad flat tabulæ. The calice is large, formed by a depression on the superior face of the tabula, and two of the primary septa, of shorter length, extend into it. This species is always simple.

Campophyllum. (Sp.)?

Plate VII., Fig. 6.

In this variety the septa are of two orders. The primary extend inwards for nearly a third of the total diameter of the corallum, and the secondary septa extend inwards for two-thirds of the length of the primary; and the interseptal dissepiments are numerous, and, in a longitudinal section, exhibit a broad zone of convex vesicular tissue, convexity inwards, and pointing upwards, and arranged in oblique rows. The fossula is large. At its inner margin the tabulæ is depressed, and two of the primary septa, of shorter length, extend into it.

Height of corallum, 7 inches; diameter, 1 inch 5 lines.

Formation.—Lower carboniferous.

Locality.—Found in Petershill Quarry, Bathgate, Linlithgowshire.

This is one of the most abundant species that is found in Scotland, and always in the lower beds of shale that is interstratified with the beds of limestone.

This species is frequently found simple; it, however, is sometimes found compound. I have a slab, cut off a mass which was a simple corallum at the base, and increased by calicular gemmation, and at two feet high was three feet broad.

Campophyllum (canina) gigantea (Mich.) *Zaphrentis gig.* (M'Coy.)

Plate VII., Fig. 4.

This section represents a large specimen from Ireland. I have, however, recently discovered the same species on the banks of the Rye Water, Dalry, Ayrshire. In this species the septa are of two

orders. The primary extend inward, over the face of the tabulæ, for ten lines on the dorsal side, and on the ventral side of the corallum they are nine lines long; the secondary septa are minute, and the primary septa are frequently intersepted by lenticular convex cells, convexity pointing inwards, and there is a broad zone of interseptal dissepiments. The fossula is large, and extends inwards to near the centre of the calicular cavity; and several of the primary septa fold round and form the walls of the fossula—a character which induced M'Coy to include it with the *Zaphrentidæ*. The tabulæ are numerous, and rest upon the inner margin of the interlocular dissepiments.

Height of corallum—it is frequently found in Ireland from 12 to 15 inches, and in Scotland I have found it 6 inches; diameter of the former, 2 inches 6 lines.

Formation.—Lower carboniferous.

Locality.—Found in many localities in Ireland; and in Scotland on the banks of the Rye Water, Dalry, Ayrshire.

Campophyllum (Cyathophyllum) paracida. (M'Coy.)

Plate VII., Figs. 10, 10A, and 10B.

Represents a series of sections, and the external aspect of this species showing calicular gemmation, and in 10B and 11D, how and where the young corallites are developed. The septa are of two orders. The primary extend inwards for a third of the total diameter of the corallum, and at their inner ends rest upon the tabulæ. The secondary septa pass inwards for two-thirds of the length of the primary, and each is united by rectangular interseptal dissepiments, which, in a longitudinal section, exhibit a broad zone of convex cells, convexity inwards, and arranged in oblique rows; and the tabulæ are dense, and more or less horizontal, and at their lateral margins they rest upon the inner margin of the concave interlocular dissepiments. The fossula is indistinct. This species is frequently found simple, but is usually found in compound communities. Gemmation may begin at any stage. I have one specimen only a quarer-of-an-inch long, and there are four corallites developed on its calice, and these are fully a line long.

Height, variable; I have a specimen 3 inches long; diameter at the widest, about 8 lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow; Broadstone, Beith, Ayrshire, and in many other localities throughout Scotland.

The foregoing may be summarised briefly as follows:—

(1). Fig. 9. *Campophyllum Murchisoni* (E. and H.). In this species the septa are of two orders. The primary are limited in their extension inwards. The secondary are abortive, and is thus a near ally to the genus *Calophyllum*, indeed, it may with propriety be said to be an intermediate between the latter genus and the more highly-developed species of the former. It, however, differs from *Calophyllum*, in the possession of a zone of vesicular tissue around the peripheral zone, and in the more pronounced septal fossula; while in *Calophyllum* the septa extend to the wall, and the interseptal dissepiments are indicated—characters which further indicate that there is a constant and persistent tendency to modification and transition.

(2). Fig. 5 exhibits a further development of the septa, and the vesicular tissue is more developed in the interseptal spaces; and Fig. 8 indicates the introduction of a columella.

(3). Fig. 11. In this species there is a further development of the septal system, and interseptal dissepiments are greatly increased, and the tabulæ is proportionately circumscribed.

(4). Fig. 4 represents a species in which the septa are considerably increased in their extension inwards, and the zone of vesicular tissue is much broader, and the primary septa are more or less intersepted by lenticular cells, and consequently some of the septa do not extend outwards to the theca, and, in this respect, foreshadows the broad zone of cellular tissue that is found to intersept the outward extension of the septa in the genera *Thysanophyllum orientale* (Plate IX., Fig. 5), Nich. and Thom., and also in *Lonsdaleia*, of M'Coy. In *Thysanophyllum* tabulæ are developed in the central area, and in this respect it may be said there is a close affinity. The latter, however, is in compound communities, and the vesicular tissue is circumferential, and developed between the wall and the outer ends of the septa. In *Thysanophyllum minus* (Plate IX., Fig. 4), N. and Th., a septum extends inwards to the centre of the vesicular chamber, and thus indicates a transition from that genus into the genus *Lonsdaleia*, and I believe that other intermediate species will yet be discovered which will show the transition more nearly related. Indeed, it is possible that in the species which Keyserling referred to the genus

Lithostrotion, the relation may be more pronounced, and thus illustrate that there is not only a constant tendency to variation in the simple forms, but that even those transitional characteristics merge and unite even the separate orders.

(5) Fig. 6 represents a section of what has been regarded as *Cyathophyllum Wrighti*. In the absence of a representation of the structural details of that species its specific characters cannot be defined. There is a further development of the septa and interseptal dissepiments, and the structural details are more pronounced.

(6) Figs. 10, 10A, 10B, 10C, and 10D. The whole structural details differ so widely from the preceding by its compound development, and its near relation to the genus *Diphyphyllum* of Lonsdale, that, indeed, I did for some time regard this species as a variety of *Diphyphyllum*. It, however, differs from the latter by the fact that it is more highly developed and gemmation is calicular, and, upon the whole, its relations are nearly allied to the genus *Campophyllum*. In this, as in all the other varieties of this group, the differentiated characters are so close, and the transitional tendencies so constant, that the overwhelming evidence is forced upon us, that there is a constant and persistent inclination to modification, arising from the endemic inclination to variation. Figs. 10C and 10D represent *Cyathophyllum echinata*. (Thom.)

In thus tracing the generic relations of the fossil remains of the *Hydroida* of the carboniferous system, although fragmentary and imperfect. Yet I hope the results of our investigations, so far as they go, will at least lead those that are interested to know wherein the *Zoantharia rugosa* differ from those groups I have imperfectly reviewed. I will now try and trace their relationship, and inquire wherein they differ from the preceding, and their connection with those afterwards to be considered.

ZOANTHARIA RUGOSA.

The *Zoantharia rugosa* includes a series of organic remains whose gemmation is by buds, and the young remain attached and form compound communities, and include a series of forms of an extremely varied aspect, whose structural details are of a most varied and diverse character.

Genus DIPHYPHYLLUM. (Lonsdale.)

Generic Characters.—Corallum compound, and formed of long

slender, cylindrical corallites, which are usually at some little distance apart, and grouped together into fasciculate masses. The epitheca is moderately stout, and development is either by fissiparity or by calicular gemmation. The septa are well developed and lamellar, and there are interlamellar stria. The primary septa extend inwards for a third of the total width of the corallum. The secondary usually extend inward half the length of the primary, and each is united by rectangular interseptal dissepiments. The fossula is small, and indicated by a slight depression of the tabula, and a septum, of shorter length than the others, extends into it. The longitudinal section (Pl. VIII., Fig. 1A) is biareal and exposes the broad tabulæ, and these bend down at their latter margins and rest upon the vesicular tissue of the peripheral area. Some of the tabulæ only extend to the centre of the corallum; they then bend downwards. A transverse section along the bent part would indicate a columellarian line, and would thus mislead the observer, and induce him to regard such forms as having a columella (Pl. VIII., Fig. 3). Indeed, I am convinced that this is the cause of so many diverse opinions regarding the classificatory value of this group. In the peripheral zone there are two convex cells convexity inwards. These are arranged alternately, and the outer ends of the bent tabulæ rest upon the cellular tissue.

In Mr. Lonsdale's original definition of the genus *Diphyphyllum*, there is only one point that I have failed to corroborate—*i.e.*, the triareal arrangement of the structural details. This I have in no instance found, and I believe that he mistook the bent ends of the tabulæ for the vesicular tissue of the interlocular area. In every other respect this definition I cordially endorse.

Prof. M'Coy (Brit. Pal. Foss., p. 87) recapitulated the definition of Lonsdale, and described two species—viz., *Dip. gracile* and *Dip. latiseptum*.

Milne-Edwards and Haime (Pol. Foss. des Terr. Pal., p. 446) considered *Dip. concinnum* (Lonsdale), was founded upon a *Lithostrotion*, in which the columella had been accidentally destroyed, and therefore rejected the genus altogether. De Fromental subsequently adopted the same views, but retains the name of *Diphyphyllum* for the fasciculate species of *Lithostrotion*. Professor de Köninck, however, by his accurate description and figures of the type form *Diphyphyllum concinnum* (Lonsdale), has thoroughly established the correctness of Mr. Lonsdale's original views, and the validity of the genus (Nov. Rech. der le Ann.

Foss., Part I., p. 36, Pl. II., Figs. 4 and 4D, 1872). The latter did not agree with Lonsdale in regarding fissiparous division to be one of the characters of the genus. As regards the classificatory position of *Diphyphyllum*, it is clearly separated from *Lithostrotion* by the fact that in the latter there is always a columella, while in the former the tabulæ closes in the floor of the calicular cavity, and there is no columella; but, as formerly stated, if a transverse section is made through the centre of the down-curved ends of those tabula that only reach to the centre of the corallum, that structure would naturally be mistaken for a columella. If, however, there is a transverse and longitudinal section, there need be no reasons for doubt as to the difference of the structural characters of *Diphyphyllum* and that of *Lithostrotion*, in spite of the close external resemblance between the two groups.

If the definition I have indicated be accepted, the genus *Diphyphyllum* will include several species that have been grouped with the genus *Lithostrotion*. But in this group, as in all the other genera, their structural characters indicate relationships so close to allied groups that it becomes difficult to define their generic distinctions. I may say, however, that I have been alone guided by the examination of a large series of sectioned specimens, in which are included specimens whose transitional tendencies are of an extremely minute character. I have also had the privilege to examine a series of specimens which Professor De Köninck kindly forwarded to me, and after careful comparison I find a somewhat common variety that is found in Scotland agree in every detail with *Diphyphyllum concinnum*, as defined by the eminent and accurate Belgian author.

The genus *Diphyphyllum* is also closely allied to the genus *Campophyllum*, as defined by me. From the typical species of the *Campophyllum*, the species of *Diphyphyllum* are separated by the limitation of the septa of the latter to the external portion of the corallum, and the fasciculate aspect of the communities. There is, however, species in the latter in which the septa are equally limited in their extension inwards, as in *Campophyllum Murchisonia* (Edwards and Haime), and *Campophyllum paracida* (M'Coy), the septa falls far short of the central area. The latter, however, are never developed in fasciculate compound masses, while in the former the different species are always formed in compound fasciculate communities, and frequently of great dimensions.

Diphyphyllum concinnum. (Lonsdale.)

Plate VIII., Fig. 2.

Specific Characters.—Corallum compound, tall, cylindrical, and in fasciculate masses. The epitheca is thin, there are longitudinal stria, and faint indications of annulations of growth. The calice is moderately deep, and its floor is occupied with broad flat tabula. The septa are of two orders. The primary septa extend inwards for a line, and rest upon the tabulæ, and these alternate with an equal number of secondary, which extend inwards for three-fourths of the length of the primary septa, and each is united with rectangular interseptal dissepiments in the outer zone, and are sparse and remote in the inner half of the interseptal locula. There are twenty-eight primary, which alternate with an equal number of secondary septa, in a corallite $3\frac{1}{4}$ lines in diameter. The fossula is small and indistinct.

Formation.—Lower carboniferous.

Locality.—Kirtle Bridge, Dumfriesshire.

Diphyphyllum fasciculatum. (D. Orb.)

This species is distinguished by the broad flat tabulæ—the septa and interseptal dissepiments not being so numerous—and by the long and distant bifurcating corallites, and by the less dense fasciculate masses.

Formation.—Lower carboniferous.

Locality.—Found at Boghead, Lesmahagow, Lanarkshire.

Diphyphyllum interruptum. (Thomson.) Sp. nov.

Plate VIII., Fig. 3.

Specific Characters.—Corallum in compound fasciculate masses, and developed by fissiparous gemmation. The epitheca is thin, and there are encircling lines of growth. The calice is moderately deep, and in some of the corallites there is a central pseudo-columella present, arising from the section passing through the down-curved part of the tabulæ that only extends to the centre of the corallum, thus indicating a transitional tendency, by the extension of a portion of the tabulæ being interrupted and bending downwards in

the centre of the calicular fossa. In a corallum 2½ lines in diameter there are 26 primary septa, and these alternate with an equal number of secondary septa, and each is united by minute interseptal dissepiments. The fossula is obscure.

Formation.—Lower carboniferous.

Locality.—Found at Boghead, Lesmahagow, Lanarkshire.

Diphyphyllum approximatum. (Thomson.) Sp. nov.

Plate VIII., Fig. 1.

Specific Characters. — Corallum compound, and in closely-aggregated fasciculate masses. The epitheca is stout, and there are encircling lines and broad irregular annulations of growth. The calice is moderately deep, and its floor is occupied with broad flat tabulæ. Some of these are more or less interrupted and bend downwards to the inferior tabula, and indicate their transitional nature, which, with further development, would merge into those genera in which the columella is of generic importance. The development of this species is by calicular and fissiparous gemmation. The septa are short; and in a corallum fully 5 lines in diameter there are thirty-two primary, which alternate with an equal number of secondary septa. The secondary curve and become attached at their inner ends to the neighbouring septa, and each is united by interseptal dissepiments, which are numerous in the peripheral zone and sparse in the inner area.

Formation.—Lower carboniferous.

Locality.—Found at Petershill, Bathgate, Linlithgowshire, and Langside, Beith, Ayrshire.

This species is readily distinguished by its more massive form and its dense fasciculate communities, and approximates so near to *Campophyllum paracida* (M'Coy), that if examined separately it might be mistaken for that species. It, however, differs by the presence of the broader tabulæ and the fasciculate mode of development, and thus forms an approximate passage between those two genera.

There is, however, another species in which the septal system extend considerably further inwards to the centre of the corallum; and in some of the corallites the septa converge inwards and unite in the centre, and thus indicate a near relation to *Lithostrotion junceum* (Flem.). This and other species I purpose by and by to

delineate and describe—meanwhile I merely wish to record this remarkable transitional tendency.

As regards the generic relations of the genus *Diphyphyllum*, it forms a natural and intermediate group between the genus *Campophyllum* on the one hand, and the genus *Lithostrotion* on the other. From the former it is distinguished by being developed in compound fasciculate masses, and by fissiparous gemmation; and from *Lithostrotion* by the fissiparous mode of development. The tabulæ extend across the centre of the corallum, fold down on either side, and rest upon the vesicular tissue of the peripheral zone, indicating an intermediate and transitional tendency from those forms in which the septa are developed and extend outward over the superior face of the tabulæ—as in the *Hydroida*—and merging and uniting those groups in which the development is by calicular gemmation, and the young grow side by side with the parent, and form dense fasciculate compound communities, which, with further development, will merge into those groups in which the septa extends uninterruptedly from the inferior to the superior extremity of the corallum—thus illustrating the principle that variation is persistent, and that modification may be traced in the development of all the different parts of a corallum, and that the species are more or less polymorphic, and that, unless approximately known in each different part, and the tendency of each section to differentiation, we can form but a very imperfect conception of the true characteristics of these coralline remains.

As above referred to, the genus *Diphyphyllum* has a close and intimate relation to the genus *Lithostrotion*. There is, however, another group—*Thysanophyllum*—which, although generically different, yet, in the form and arrangement of the tabula in the central area, they are more or less related. But, from the fact that in one species of *Campophyllum* (*i.e.*, *Camp. gigantium*), there is indicated a transitional tendency in the vesicular tissue of the peripheral zone, by the fact that the prolongation of the septa are more or less arrested, they being here and there intercepted by vesicular tissue. In this respect the latter genus may be said to have a near relation to the genus *Thysanophyllum* (Nich. and Thom.). In order that the relationships of each may be traced, and the connecting links understood, I will now briefly refer to the structural details of the latter genus, and see wherein the development of the group warrants us in believing that there is a

progressive development foreshadowed and exemplified throughout the whole series.

Genus THYSANOPHYLLUM. (Nicholson and Thomson.)

Plate IX., Figs. 5 and 5A.

Generic Characters.—Corallum compound, fasciculate or astreaform, increasing by latro-calicular gemmation. Each corallite is provided with a distinct wall, and there is an inner mural investment developed. The calice is shallow, and the centre of its floor is occupied by broad and remote tabulæ. The septa are abortive. In one species the primary septa are lamellar, and there are no secondary septa; whilst, in another species, the septa are of two orders. The primary septa extend from the vesicular tissue inwards to the tabulæ, and the secondary septa extend inwards for a fourth of the length of the primary septa, and each is united by slightly angular interseptal dissepiments, which are sparse near the inner margin of the primary septa, and where they approach the vesicular tissue of the outer zone they are more numerous. The longitudinal section is triareal. The central area is composed of remote transverse tabulæ. The intermediate ("interlocular") area is composed of remote convex tabulæ, convexity pointing upwards and inwards. The outer area is occupied with a zone of elongated convex vesicular tissue, convexity pointing outwards and inwards, and arranged in oblique rows.

The genus *Thysanophyllum* (Nich. and Thom.) is related to the genus *Lonsdalia* (M'Coy, Plate IX., Figs. 1 and 2) in the general form of the corallum, in the presence of an exterior vesicular zone of large cells, and in the possession of septa which have no connection with the outer wall. It is distinguished, however, by the fact that there is no true columella, and there is always a conspicuous central tabulate area uncovered and exposed to view in the former; whilst in the latter, the centre of the calicular cavity is occupied by a prominent boss, and by the possession of a median columellarian line, which extends from the superior to the inferior extremity of the corallum, which is surrounded by convex vesicular tissue, convexity pointing upwards and inwards.

In the longitudinal section are present characters in the central area, which might be mistaken for some of the simple forms of *Campophyllum*. From the broad tabulate forms of *Campophyllum*

the genus *Thysanophyllum* is at once distinguished by the fact that the septa extend to the outer wall in the former, with one exception, whilst in the latter the septa never reach the outer wall, but are intersepted and surrounded by a zone of vesicular tissue, which occupies the intermediate space between the outer ends of the septa and around the peripheral zone of the corallum. As referred to above, there is one notable exception in the latter structural details—*i.e.*, *Campophyllum giganteum*. The septa in that species are more or less interrupted by lenticular vesicular tissue near the periphery, and therefore indicating a transitional tendency. Indeed, I am satisfied that other intermediate forms will yet be discovered that will still more closely unite those genera. Meanwhile, with our present knowledge, we can only regard the remarkable vesicular tissue in *Thysanophyllum*, and as indicated in *Campophyllum gigantea*, as foreshadowing a transitional condition, which, with further development, will unite those genera more closely. *Thysanophyllum* presents characters in the central area which are also characteristic of the genus *Phillipsastrea*. In the latter the central area is occupied with transverse tabulæ in some forms, whilst in others the tabulæ are more or less inclined upwards, and unite in the centre, and in one species a portion of the septal system extends inwards to near the centre of the calicular cavity; they then coalesce, and meet in the centre of the corallite—a character which is also characteristic of *Lithostrotion junceum*, and more fully developed in the genus *Heterophyllum*. It will thus be apparent that the genus *Thysanophyllum* is polymorphic, and that its relationships diverge in all directions; and although there has been only two species discovered, yet in these the endemic tendency to variation is well exemplified.

Thysanophyllum orientale. (Nicholson and Thomson.)

Plate IX., Figs. 5 and 5A.

Specific Characters. — Corallum compound, in fasciculate or astreaform masses; development by calicular gemmation. The epitheca is stout, there are longitudinal ribs and obscure annular ridges. The calice is moderately deep, and its margin is sub-mammillated, and the floor is occupied by flat tabulæ. The septa are bilamellar, and they never extend to the periphery, but are

intersepted by the mammillate tissue. In an ordinary-sized corallite there are about 30 septa, which extend from the tabulæ of the central area to the vesicular area of the outer zone. The longitudinal section (Fig. 5A) exhibits the cut edges of the transverse tabulæ of the central area, and the large vesicular convex cells in the outer area, convexity pointing upwards and inwards.

Height and diameter of corallum variable.

Formation.—Lower carboniferous, and found associated with *Diphyphyllum fasciculatum*, near Fenwick, Ayrshire, and with *Lithostrotion junceum*, on the shore of Aberlady Bay, Haddingtonshire.

Thysanophyllum minus. (Nicholson and Thomson.)

This species differs from the former in the possession of flexuous septa, and one of them extends to the centre of the visceral chamber, and in this respect indicates the generic character of the genus *Lophophyllum*. The other septa never reach the periphery, but are intersepted by a zone of large cellular tissue. In all respects this species agrees with the former, except in the extension of one of the septa into the centre of the calicular fossa, which may be regarded as the indication of the transitional tendency of the genus.

It will be seen from the above that the structural characters which collectively distinguish the genus *Thysanophyllum* are—(1) the presence of broad flat tabulæ; (2) the aborted septa; (3) the zone of vesicular tissue that extends from the outer ends of the septa to the wall.

With regard to the affinities of the genus, it possesses characters of an unusually fundamental nature; and although surrounded by genera that possess certain structural details which are combined and represented in *Thysanophyllum*, yet, like all the other genera of this interesting series of coralline remains, there is clearly indicated transitional tendency which unites it to other allied forms. Indeed, if there was no other genus than this discovered in it, we would have structural details sufficient, with our present knowledge, to indicate how little we yet know of the true characteristic of this great group, and how diverse our acquaintance with the allied forms requires to be before we can even approximately realize how widely dissimilar, and yet how clearly they each

indicate the unity of development, and how harmonious the transitional tendencies are to universal variation.

During our inquiry into the generic relations of each group, we have found that in each there is a constant tendency to variation, and that these modifications indicate an endemic tendency to become more complex in their organization, and that with increased complexity there is a proportionate increase in the extension or inward prolongation of the septal system. I will now consider the generic relations of a group in which the septa converge inwards to the centre of the corallum.

Genus CYATHOPHYLLUM. (Goldfuss.)

Generic Characters.—Corallum simple or compound; the epitheca is variable, the calices are variable in depth and form, and the septa usually converge inward to the centre, where they partially coalesce or are twisted together, and thus form a spurious columella. The septa are of two orders. The primary extend inwards to the centre, and the secondary extend inwards to variable distances, and each is united by interseptal dissepiments, which are usually numerous in the outer zone and sparse towards their inner ends. The septal fossula is variable in size and form in the different species.

The longitudinal section exhibits tabulæ in the central area, which at the lateral margins rest upon a system of convex cells, convexity upwards and outwards, and which fills in the intermediate ("interlocular") area, and the outer area is occupied by a broad zone of interseptal cellular tissue, convexity pointing upwards and inwards, and arranged in oblique rows.

As regards the structural characters, the corals which are referable to the genus *Cyathophyllum* appear to be marked out with sufficient distinctness. The tabulæ are considerably more circumscribed in the central area than is found in *Campophyllum*, its nearest ally, and are usually very closely set, and surrounded by a broad zone of delicate vesicular tissue, which in the outer ("interseptal") area is dense, and more or less sparse in the "interlocular" area. The septa are well developed, and usually extend inwards either to or near the centre, and in some forms they are more or less twisted together, and slightly raised in the centre of the central area (Pl. VII., Fig. 2). In some forms that

were included in the genus *Cyathophyllum* proper the septa stop short at some distance from the centre, as in *Campophyllum (Cyathophyllum) paracida* (M'Coy). Such, however (as formerly stated, when referring to the relationships of the genus *Campophyllum*), cannot be regarded as belonging to the genus *Cyathophyllum* proper, as defined by Goldfuss in his original description. He defines the genus as possessing septa which converge inwards to the centre of the corallum, and unite and curve upwards at their inner ends.

It will thus be apparent that the structural characters which distinguish the genus *Cyathophyllum* are—(1) the presence of closely-arranged tabulæ in the central area; (2) the existence of a broad exterior zone of vesicular tissue, formed by extensively-developed interseptal dissepiments; (3) the extension of the septa into the central area, which are, at their inner ends, curved upwards, and are more or less twisted. There are, however, exceptions to the latter structural arrangement of the septa. In some forms the septa do not quite reach the centre of the corallum, as in *Cyathophyllum cuspidaphyllia* (Thomson, Plate VII., Fig. 3); and in *Cyathophyllum Murchisoni* (Edwards and Haime, Plate VII., Fig. 1), their inward extension is considerably less apparent, arising from the fact that at the inner area of the septal system they are considerably curved upwards. Indeed, the central area presents a more or less dome-shaped aspect, exposing the minute flate (tabulæ) in the centre of the central area, and thus indicating a transitional tendency, and may be regarded, by the presence of the calicular boss, as indicating the mergence of the genus *Cyathophyllum* into the genus *Koninckophyllum*. The latter, however, is at all times distinguished by the presence of a columellarian rod in type specimens. There are, however, transitional forms in which the extension from the inferior to the superior extremity of the corallum of the columellarian rod is interrupted (Plate XI., Fig. 3A). In all instances, however, where the central area is more or less elevated, we have the clearest evidence of a transitional tendency, and their mergence can be shown in the modified aspect of the central area to unite the former genus with the latter on the one hand, and on the other *Cyathophyllum* is intimately related to the genus *Campophyllum*.

Cyathophyllum regium. (Phillip.)

Plate VII., Figs. 2 and 2A.

Specific Characters.—Corallum compound, massive, and astreaform. Calices polygonal, shallow, and unequal in size, and separated by an irregular or sinuous wall. The septa converge to the centre in some corallites, and a portion of them unite in the centre of the central area, whilst in others they do not quite reach the centre. At their inner ends they are curved upwards and present a more or less tumid aspect, and these alternate with an equal number of secondary septa, which extend inwards from the wall for three-fourths of the length of the primary septa, and each is united by rectangular interseptal dissepiments, which are somewhat large around the periphery, and dense and minute a short distance from the outer margin, and at the inner end ("interlocular") area they are sparse. A septal fossula is present, but usually indistinct.

The longitudinal section exposes the tabulæ of the central area, which at their lateral margins extend into, and rest upon the vesicular tissue that fills up the intermediate ("interlocular") area. These are convex, convexity pointing outwards and upwards. The outer ("interseptal") area is occupied by a broad zone of convex vesicles, convexity pointing upwards and inwards, and arranged in oblique rows.

Corallum found in great masses. Plate VII., Fig. 7, a young specimen of the same.

Formation.—Lower carboniferous.

Locality.—Found in Petershill Quarry, Bathgate, Linlithgowshire, and Blackridge, Dumfriesshire.

Cyathophyllum Murchisonia. (Edwards and Haime.)

Plate VII., Figs. 1 and 1A.

Specific Characters.—Corallum compound, massive, and astreaform. The calices are polygonal and everted, and abruptly domeformed in the centre, and expose the flat tabulæ in the centre of the central area. The septa do not quite reach the centre, and are of two orders. The secondary septa extend inwards from the wall for about half the length of the primary septa, and each are

united by rectangular interseptal dissepiments, which are dense in the peripheral zone and sparse in the inner area. The septal fossula extends in to near the centre, and the tabula is depressed at its inner end. The epitheca is delicate but well defined.

The longitudinal section exposes the comparatively broad tabulæ, which at their lateral margins bend downwards and rest upon the ("interlocular") dissepiments, which are convex, convexity pointing upwards and outwards. The outer ("interseptal") area is occupied by lenticular convex cellular tissue, convexity pointing upwards and inwards, and arranged in oblique rows.

Corallum found in great masses.

Formation.—Lower carboniferous.

Locality.—Found at Blackridge, Dumfriesshire.

Cyathophyllum cuspidaphyllia. (Thomson.) Sp. nov.

Plate VII., Fig. 3.

Specific Characters.—Corallum simple, tall, and curved. The epitheca is moderately stout, and marked with encircling lines and irregular annulations of growth. The calice is shallow and thin at the margin. The septa converge inwards to near the centre, they then curve upwards and are more or less united in the centre, and form a slightly conical boss in the centre of the corallum. In the transverse section the septa are thin at their outer ends, becoming stout in the intermediate area, and delicate and pointed or cuspidate at their inner ends.. The septa are of two orders, and lamellar in the intermediate area, and thin and more or less flexuous in the outer zone. There are thirty primary septa, and these alternate with an equal number of secondary septa, and each is united by rectangular interseptal dissepiments. The fossula is large and extends into near the centre of the corallum, and four of the septa, of shorter length than the others, extend into it.

Formation.—Lower carboniferous.

Locality.—The figured specimen is from Ireland, and in the Geological Survey Collection. I have, however, lately discovered the same species at Brockley, Lesmahagow, Lanarkshire.

From the above descriptions it will be apparent that the structural details of the different species of *Cyathophyllum* indicate clearly that in this genus, as in all the previous genera, there are modifications in the structural details; that while there is indicated

a near relationship, yet the arrangement of these details point to their variable character, and from the variability of these details there is the clearest indication of wants or breaks in the continuity of the series. Indeed, if my time would have admitted, I could have included other forms that would still more closely unite the series. Meanwhile the evidence offered, along with that adduced through the structural details of allied genera, is sufficient to show that variation is abundantly illustrated in every detailed part of the corallum, and gives the clearest evidence that each variety has been modified, either from external causes affecting and altering the soft tissues of the animal, or induced by other causes which, with the paucity of our present knowledge, is meanwhile obscured.

From what has been indicated, it will be apparent that in the further continuation of our inquiry, the group that falls to be considered is more or less related to the latter, by the system of transverse tabula in the centre of the corallites and their compound astreaform communities, and which include the

Genus PHILLIPSASTRÆA. (Edwards and Haime.)

Generic Characters.—Corallum compound, and formed of vertical cylindrical corallites, and developed by fissiparity, and present astreaform masses of varied thickness, and in slightly concave groups, from two lines to three inches in thickness. The corallites radiate with uniform divergence from the primary corallite, which seems to have been attached to some foreign body. The epitheca is thin, and marked with irregular broad annulations of growth; and delicate stria radiate from the central parent corallite to the circumference. The septa are bilamellar, and extend to irregular distances outwards, and at their outer extremities they are more or less confluent. I have not detected a fossula. In some forms the septa terminate at the margin of the central area; in such forms the floor is occupied with flat tabula. In another variety one septum extends into the centre, and is seen as a raised ridge, and more or less clavate at its inner boundary. In another variety the circumference of each corallite is elevated, and is therefore mammillated; and there is a prominent columella, and its superior extremity is raised above the calicular cavity.

In another species a portion of the septa coalesce, and become more or less fasciculate, and the centre of each fascicula extend into

the centre of calice, which, in a longitudinal section, indicates a pseudo-columella. In a longitudinal section the tabula extend across the central area, and rests laterally upon a system of elongated convex interlocular dissepiments, convexity pointing inwards and upwards. In those forms which in some of the corallites there is an extension of a septum, the tabula here and there are seen to bend upwards, and to curve over the opposite tabula, and this accounts for the clavate aspect in the calicular cavity, and the tabulæ are therefore more or less irregular in their arrangement; while in those forms in which the septa converge and unite in the centre in the longitudinal section, in the central area a columellarian line is developed, indicating a near relationship with the genera *Lithostrotion*, and also to the genus *Heterophyllum*. In another variety the columella in the longitudinal section extends from the inferior to the superior extremity of the corallum, and the tabulæ are developed on either side. In all cases the corallites are separated by a broad zone of minute vesicular interseptal dissepiments, which are developed at varying distances apart.

Phillipsastræa radiata. (Edwards and Haime.)

Plate IV., Figs. 1, 1A, and 1B.

Specific Characters.—Corallum composite, in broad thick astreaform masses, and composed of vertical cylindrical corallites about two lines apart, and developed by fissiparity. The epitheca is thin, and there are broad irregular annulations of growth and concentric stria. The calices are about half-a-line deep, and there is a central compressed prominent columella in some coralets. The septa are confluent, and radiated outwards to unequal distances. There are thirty septa in a fully-developed corallite, which are united by rectangular interseptal dissepiments. In a longitudinal section the tabula are irregular; some are rectangular, but the great proportion are bent upwards and meet in the centre, and form a more or less discontinuous columella. The lateral margins of the cylindrical corallite are bounded by elongated convex cells, convexity inwards and upwards, and the interspaces are occupied with convex interseptal dissepiments; and opposite the base of the zones of the up-curved tabula the interseptal dissepiments are considerably stouter, thus partitioning the periodic zones of irregular tabula into periodic intervals.

Height of corallum, 2 inches; diameter of calice, 1½ line.

Formation.—Lower carboniferous.*

Locality.—Found at Blackridge, Dumfriesshire, in the shale that is interstratified with the thin bands of limestone in which *Productus giganteum* are found.

This is the only locality in Scotland in which I have, as yet, discovered this genus, and it is somewhat remarkable that all the four varieties are found in that locality.

This being the only species figured, I will briefly summarise the group as follows :—

(1) In one variety the tabulæ are all but complete.

(2) In *Phillipsastræa radiata* the tabulæ are irregular.

(3) In *Phillipsastræa sp.(?)* the tabulæ are more or less divided by a pseudo-columellarian line.

(4) In *Phillipsastræa tuberosa* the corallum is mammillated, and there is a stout laterally-pressed columella.

Thus clearly indicating that the transitional tendency is marked and easily distinguishable.

As regards the relationship of the genus, while the structural characters indicate its polymorphic nature, the group is distinguished and readily recognized. The genus, however, may be said to merge and unite the simple tabulate form of *Thysanophyllum* by the possession of the central tabulate area, and, with further development, to pass by minute transition into the development of the columella, and thus unite and correlate the more highly-developed species of *Phillipsastræa* with the species of *Lithostrotion* in which the columella is constantly present; and in those species in which a portion of the septa converge into the centre of the corallum indicates a near alliance with the astreaform species of *Cyathophyllum* and those forms in which the tabulæ bend upwards and coalesce in the centre, and assume a pseudo-columellarian road,

* This limestone is grouped as belonging to the calciferous sandstone series by the Geological Survey. I, however, venture to assert that, if the beds are intercalated with the calciferous sandstone (?) the discovery of *Productus giganteus*, and the varied forms of coralline remains that I have found there, is a discovery which calls for greater prominence than has yet been given to it.

indicates a transitional tendency in those tabulæ which converge upwards and inwards, and at their inner ends coalesce and form the conical boss, as in the genus *Lonsdalia*; therefore I regard each of those structural characteristics as indicating a marked and distinct tendency to variation, and indicating the polymorphic character of the genus, which, with further development, will merge and unite the surrounding and allied genera into a varied series of more highly-developed organisms, and fully demonstrate the all but complete proposition that in every group there is evolutionary tendencies which, if we were in full possession of all the facts, would indicate very clearly the innate tendency to variation, and that each modification indicates a progressive development.

In the successive stages of our inquiry I have introduced a series of structural details, varied in themselves, and have shown that each new detail alters and affects not only the internal, but equally influences the external aspects of each group in which these modifications are found. I shall now briefly refer to the genus *Lithostrotion* (Luid)—the varieties of which has provoked a greater variety of generic nomenclature than has fallen to the lot of any other group of these organic remains. But from the fact that Luid established in 1699 the generic name of *Lithostrotion* to include one species, whose structural details indicate a relationship of a varied character, I cordially agree with M. Edwards and J. Haime in grouping the series as belonging to that genus, *à priori* clearly precluding any other classification.

Genus LITHOSTROTION. (Luid.)

Plate VIII., Figs. 4, 5, 6, and 7.

Generic Characters.—Corallum compound, and composed of cylindrical fasciculate and astreaform colonies. Their development is usually by latro-calicular gemmation, and the young in the cylindrical fasciculate varieties grow side by side with the parent corallites, and are more or less apart. In the astreaform varieties gemmation is near the margin, and the young corallite grows nearly perpendicular, and becomes polygonal from lateral pressure. The epitheca is of variable stoutness. A columella is always present, which in a longitudinal section is seen to extend from the base to the superior extremity of the corallum, and the tabulæ

extend from the columella to the wall, while in some forms they are intercepted by a zone of vesicular tissue that surrounds the periphery. In some forms the tabulæ are rectangular, and become more or less convex, and in others the columella is surrounded by a system of convex cellular tissue, convexity pointing upwards and outwards. The septa are of two orders, and of variable length. In some forms the primary septa extend inwards to the columella, whilst in others they stop short of the centre. The secondary are minute. In some species they are united by interseptal dissepiments, and in one there is no dissepiments developed. In some of the species the septa are developed along the superior face of the tabulæ, whilst in others they extend from the superior to the inferior extremity of the corallum.

From the great diversity of structural characters referred to above, it will be apparent that the genus includes a series of organic remains of an extremely varied character, which induces me to perceive how naturally several of the authors would describe some of varieties under different generic names. Indeed, unless a series of the specimens are carefully sectioned, and their varied tendencies are minutely studied, such might be expected, as a considerable variety of them indicate such a close affinity to other allied genera that there need be no surprise felt at the variety of generic names that have been given to some of them by the different authors. To enter into the details upon which each author established their varied opinions is more than our space will admit of; meanwhile I merely wish to state that the name of *Lithodendron* was given to one group by Professor Phillips, which included those species that are in fasciculate masses. These, however, possess structural characters which are more or less found throughout the series, and I therefore feel that to designate the genus simply from the fasciculate aspect of a portion of them leads to confusion, and I believe that the classification of Edwards and Haime is confirmed by the structural details of the series.

The type species of the genus *Lithostrotion* is *Lith. basaltiform* (Luid), and may be regarded as exhibiting all the essential characteristics of the genus. I will therefore give a specific description of that species, and then refer to the specific difference of each of the species in my cabinet.

Lithostrotion basaltiform. (Luid.)

Plate VIII., Fig. 6.

Specific Characters.—Corallum compound, with astreaform, prismatic corallites, in dome-shaped masses, and developed by latro-calicular gemmation. The epitheca is thin, and there are longitudinal lines and encircling lines of growth. The calice is deep, and the centre is occupied by a laterally-compressed, thin, styliform columella. The septa are thin, and of two orders. The primary septa extend to near the centre of the calicular cavity, and the secondary extend inwards for half the length of the primary, and each is united by rectangular interseptal dissepiments. The corallites are unequal in diameter. In a corallite five lines in diameter there are twenty primary, and these alternate with an equal number of secondary septa. In a longitudinal section the columella occupies the centre of the corallites, and the up-curved tabula extends inwards from the interseptal loculi to the columella and forms the floor of the calicular cavity. The fossula is large, and three of the primary septa, of shorter length than the others, extend into it.

Height of corallum, variable; diameter—I have got them in groups less than an inch up to 11 feet.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, imbedded in the shale in the centre of the atoll that is exposed on the banks of the Solway Frith.

Lithostrotion ensifer.

This species differs from the preceding by the shallow and less defined calices. The columella is much stouter and prominent, and there are minute spines developed laterally, and situated between the inner ends of each of the septa. The primary septa extend inwards from the wall to the columella. The fossula is small, and a primary septum extends two-thirds of the length of the others into it.

Formation.—Lower carboniferous.

Locality.—Found in the centre of atoll, at Arbigland, Kirkcudbrightshire.

Lithostrotion cyathophyllia. (Thomson.) Sp. nov.

Specific Characters.—Corallum compound, and in dome-formed masses; reproduction by calicular gemmation. The corallites

are small and astreaform. The calices are deep, and in the great majority of the corallites the primary septa extend into the centre, slightly curve, and form a pseudo-columella. In others the inner ends of the septa meet, coalesce, and form a minute central plate, and therefore may be regarded as an indistinct columella. The epitheca is thin. In a corallite $2\frac{3}{4}$ lines broad there are eighteen primary septa, and these alternate with an equal number of secondary septa, which extend inwards for about a fourth of the length of the primary. At their inner ends they bend and become attached to the primary septa, and each is united by rectangular interseptal dissepiments. In some of the corallites a portion of the primary septa are intercepted by vesicular tissue, and therefore do not reach the wall—a characteristic of the genus *Lonsdaleia*. The fossula is small, and one of the primary septa, a third shorter than the others, extends into it.

Formation.—Lower carboniferous.

Locality.—Found in the centre of the atoll, at Arbigland, Kirkcudbrightshire.

A portion of the primary septa extending in to the centre of the calicular cavity, curving, coalescing, and forming a pseudo-columella, induces me to regard this species as being similar to the one that Professor Phillips described as *Cyathophyllum basaltiform*.

Lithostrotion septosum. (M'Coy.)

This species is distinguished from the preceding by its large flat calices and its small columella, which is stout in the middle area and acuminate at either extremity; also by its bilanceolate aspect. The primary septa are crenulate and more numerous, and the secondary septa extend further inwards—usually for two-thirds of the primary—and the interseptal dissepiments are angular and more numerous.

Formation.—Lower carboniferous.

Locality.—Found in the centre of the atoll, at Arbigland, Kirkcudbrightshire.

Lithostrotion aranea.

This species is distinguished from the preceding by its large corallites, and its fusiform columella. The septa are slightly flexuous, and the primary septa converge inwards. Some of them

coalesce, and only a portion of them extend to the columella. The secondary septa extend inwards for two-thirds of the primary, and each is united by rectangular dissepiments, which are numerous during the extension of the secondary septa; and at the termination of the secondary septa a dissepiment on either side curves laterally, and becomes attached to the primary septa, and in the inner area (interlocular) the dissepiments are sparse. The epitheca is stouter, and the fossula is small and indistinct.

Formation.—Lower carboniferous.

Locality.—Found inside the circle of the atoll at Arbigland, Kirkcudbrightshire.

Lithostrotion clavatica. (Thomson.) Sp. nov.

Specific Characters.—Corallum compound, astreaform, and in dome-shaped masses, and developed by latro-calicular gemmation. The calices are moderately deep, and the clavate columella is raised above its floor. The calices are irregular in size, and when fully developed are from four to five lines in diameter. There are twenty primary, and these alternate with an equal number of secondary septa. The primary extend into the columella, and the secondary septa extend inwards only half the length of the primary, and each is united by rectangular interseptal dissepiments, which are dense in the outer half and few in number in the inner half of the septa. The fossula is large, and two of the primary septa, half the length of the others, extend into it. The epitheca is stout, and along the inner margin there is dense delicate vertical stria.

Formation.—Lower carboniferous.

Locality.—Found inside of the circle of the atoll at Arbigland, Kirkcudbrightshire.

Lithostrotion Flemingi.

This species is readily distinguished from all the preceding. The calices are moderately deep, and from about two to three lines in diameter in the large and full grown corallites. The septa are numerous, and the primary extend inwards to the columella, and the secondary converge inwards two-thirds of the length of the primary septa, each being united by rectangular interseptal dissepiments, which are dense in the outer area and are sparse in

the inner zone. The wall is stout. The fossula is small and indistinct.

Formation.—Lower carboniferous.

Locality.—Found inside the circle of the atoll at Arbigland, Kirkcudbrightshire.

Lithostrotion Portlocki.

Plate VIII., Figs. 7 and 7A.

This species is distinguished from the preceding by its smaller corallites. The septa are less numerous, and the interseptal dissepiments are not so plentiful in the outer zone, and more numerous in the inner area; and the primary septa converge inwards to the columella; and the central area is more or less vesicular; and a portion of the primary septa are intersepted at their outer ends by sparse vesicles; and, on the whole, this species approaches more closely to the structural details of *Lonsdaleia floriform* (M'Coy), than do any of the other species of *Lithostrotion.*

Formation.—Lower carboniferous.

Locality.—Found in the inside of the circle of the atoll, at Arbigland, Kirkcudbrightshire; and at Corrie Burn, Dumbartonshire; and Wistown, Lanarkshire.

Lithostrotion M'Coyanum. (Edwards and Haime.)

This species is considerably more delicate than *Portlocki*, its nearest ally. The septa are more numerous in proportion to the size of the corallite, and are more or less crenulate. The primary converge into the centre, and are attached to the minute columella. The wall is much stouter, and the corallites are considerably smaller. Upon the whole, it is readily distinguished from all the other species by characters of a marked nature.

Formation.—Lower carboniferous.

Locality.—Found at Blackridge, Dumfriesshire, where it is abundant and in great masses; and at Catcraig, near Dunbar, Haddingtonshire.

I shall now briefly refer to the structural details of the fasciculate varieties.

Lithostrotion junceum. (Fleming.)

Plate VIII., Figs. 4 and 4A.

Specific Characters.—Corallum compound, cylindrical, and not unfrequently found in dense fasciculate masses. In several localities it is found in reefs of large dimensions. Reproduction is by latro-calicular gemmation, and the corallites are long and slender, and usually about a line in diameter. The calices are shallow, and the primary septa extend inwards along the superior face of the tabula to near the centre, where they coalesce, and a few of them are united with the minute columella. If, however, a section is made through the tabulæ, the septa are not observable. The septa are of two orders—the secondary are minute, and there are no interseptal dissepiments. The tabulæ are more or less convex near the columella, and at their outer ends they bend downwards and become united to the wall. A septal fossula is indicated. The columella in a longitudinal section is exposed, extending from the inferior to the superior extremity of the corallum. If, however, a section is made a little off the centre, it is not observable. The epitheca is stout, and there are prominent encircling lines of growth.

Height of corallum, variable—I have some corallites 3 inches; diameter, 1 line.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Braidwood, and Wistown, Lanarkshire; Bathgate, Linlithgowshire; Catcraig, Dunbar, and Aberlady Bay, Haddingtonshire, where it is in great reefs; and Asheyburn, Muirkirk, where the reefs are of gigantic proportions. Indeed, the species is found throughout Scotland in and under the main limestone in all the beds but the lowest. I have not found it in that bed.

Lithostrotion. Sp. ?

This species differs from the preceding in the corallites being fully more than a half larger, and there are interseptal dissepiments, and the tabula in a longitudinal section are alternate, and extend inwards and upwards at an acute angle to the columella. The columella is much stouter, and in the transverse section the primary septa extend inwards to the stout columella. The secondary septa are minute, and each is united by interseptal

dissepiments; and, upon the whole, the structural details indicate a near alliance to the structural characters of *Lithostrotion Portlocki*. It, however, differs in being fasciculate and wide apart, and the secondary septa are never so long as in *Lithostrotion Portlocki*.

Formation.—Lower carboniferous.

Locality.—Found at Meadowfoot, near Drumclog, Ayrshire.

Lithostrotion irregulare. (Phillips.)

This species differs from all the others by its short septa, which never reach the centre of the calicular cavity; the centre is occupied with flat tabulæ, and there is a laterally-compressed columella, and the longitudinal section exposes the thin columella extending through the flat tabulæ, which occupies nearly two-thirds of the total diameter of the corallum, and at about a fourth of their width they bend acutely downwards, and rest upon the interlocular tissue. The wall is stout, the corallites cylindrical, fasciculate, and irregular.

Formation.—Lower carboniferous.

Locality.—Found at Roughwood, Beith, Ayrshire; and Corrie Burn, near Kilsyth, Dumbartonshire.

Lithostrotion Martini. (Edwards and Haime.)

This species is readily distinguished by the size of the corallites, which are from 5 to 6 lines in diameter, the broad tabulæ, and the small compressed columella. The primary septa extend inwards for about a fourth of the total diameter of the corallum, and the secondary septa about half the length of the primary, and each is united by interseptal dissepiments. In a longitudinal section, the tabulæ are flat in the centre, bend down at their lateral margins, and rest upon the vesicular tissue in the peripheral zone, and are a line apart.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, Kirkcudbrightshire, and is one of the species, with others, that form one of the fringing reefs around the atoll of that locality.

Lithostrotion Phillipsi. (Edwards and Haime.)

Plate VIII., Fig. 5.

This species is tall, cylindrical, and fasciculate, and is never so

large as the preceding, and are frequently coalescent. The septa do not extend so far into the centre; the columella is stouter; the tabulæ rest upon the vesicular tissue in the peripheral zone. They bend upward, then become concave, and bend upwards at their inner ends, and are attached to the stout columella. It differs from *Lith. Martini*, its nearest ally, by its smaller corallites, its stouter columella, and the concave tabulæ.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, Kirkcudbrightshire. This species is intermixed with others which go to form one of the encircling reefs around the atoll of that locality.

The genus *Lithostrotion* is such a comprehensible and variable one, that I have thought it advisable to give a brief account of the more important structural characters. By-and-by I purpose to delineate the series, and give a detailed description of each of the species; meanwhile, I will summarise those structural details which indicate transitional tendency.

(1) The genus *Lithostrotion* resembles *Diphyphyllum* in the external appearance—indeed, some of the species of the latter are often confounded with the former. In the latter genus, however, there is never a columella, and the short septa always leave a conspicuous central tabulate area uncovered and exposed to view, so that there need be no misunderstanding or confounding *Diphyphyllum* with *Lithostrotion*, except as regards the fasciculate aspect. If, however, a transverse section is examined they are readily distinguished by their structural details.

(2) *Lithostrotion junceum* indicates a transitional tendency towards the genus *Heterophyllum* by the coalescence of a portion of the primary septa and the extension of a portion of them to the centre. From *Heterophyllum* it is at once distinguished by the cylindrical corallites and the fasciculate compound communities.

(3) In *Lith. basaltiform* and *Lith. Portlocki* there is indicated in the cellular tissue around the columella a near relationship to the genus *Lonsdaleia*. In *Lith. Portlocki* there is a system of convex cells that surround the columella—convexity pointing upwards and inwards—somewhat similar to the cellular tissue that is found in the central area of *Lonsdaleia*, and in both genera there is the central columellarian rod, characters which induced Prof. Fleming to include *Lonsdaleia floriformis* as belonging to *Lithostrotion*. In *Lonsdaleia* the extension of the septa outwards to the wall is interfered with by the presence of a zone of vesicular tissue around

the peripheral zone. In *Lith. basaltiform* and *Lith. Portlocki* there is a transitional tendency to the outer zone of vesicular tissue indicated by the fact that a few of the septa are intercepted by a convex cell—convexity pointing inwards, as in *Lonsdaleia*—and I believe other forms wait sectioning to exhibit a more intimate relation between those genera.

(4) From the fact that the primary septa in a number of the corallites extend inwards, curve, and unite at their inner ends—which is the essential structural character of the genus *Cyathophyllum*—implies that in this species a portion of the corallites exhibits a modified condition of the genus *Cyathophyllum*, and that the tendency is to merge and unite those genera, and illustrates the opinion that it is difficult to define the line of demarcation between even genera.

(5) In *Lith. clavatica* the extension of one of the septa to the clavate columella is similar to the structural character which induced Edwards and Haime to found the genus *Lophophyllum*. In the latter, however, there is never tabulæ present in the central area. The inner ends of the septa extend uninterruptedly from the inferior to the superior extremity of the corallum, while in *Lithostrotion* there is always tabulæ present.

It will thus be apparent that amongst the species of this genus there are structural details of an extremely diverse character, including species which illustrate their polymorphic tendencies, and indicates that variation is so persistent that, in tracing by means of these minute transitions, there is no limit to the endemic tendency to modification. In this group, as in all the others, there is a more or less near alliance throughout the entire series of these organic remains. As we have seen, the genus *Lithostrotion* is more or less related to the genus *Lonsdaleia*. I will therefore briefly trace how far the structural characters of that genus bear out the general proposition that reproduction aad variation is the ultimate of universal law and order.

Genus Lonsdaleia. (M'Coy.)

Plate IX., Figs. 1, 2, and 3.

Generic Characters.—Corallum compound, fasciculate or astreaform, and developed by calicular gemmation. The epitheca is stout. There is a circumferential zone of irregular convex vesicular tissue, convexity pointing inwards, through which the septa

never extend to the wall. The calice is deep, and in the centre of its floor there is a conical boss, formed by a system of lamellæ, which are united by interlamellar dissepiments, which in a longitudinal section are exposed as elongated convex cells, convexity pointing outwards. At their inner ends they converge, and become united, and form a pseudo-columella.

The corallum in *Lonsdaleia* is in compound masses, and, in favourable circumstances, may be traced from the parent corallite, and the young corallites, being developed by calicular gemmation, are seen arising in the outer zone of vesicular tissue, and growing uninterruptedly upwards. In some forms—as *Lon. duplicata* (Mart.)—the corallites always remain free laterally. In others—as *Lon. floriformis* (Flem.)—they become united laterally, and assume a polygonal form from lateral pressure (Plate IX., Fig. 3); whilst in *Lon. rugosa* (M'Coy) there is an intermediate state of parts, and the corallites, although more or less free laterally, sometimes become partially amalgamated (Plate IX., Fig. 1).

The structural details of the genus *Lonsdaleia* are so well marked that there is little chance of its being confounded with any other. From *Lithostrotion* it is at once distinguished by the fact that the septa are not in direct connection with the outer wall. This is not, however, confined to *Lonsdaleia*. In the preceding pages we found that in the genus *Thysanophyllum* a similar vesicular tissue intercepted the extension of the septal system. In the latter genus, however, there is no columella, and the central area is occupied with irregular tabulæ. In *Lonsdaleia* the central area in a transverse section is occupied by a system of lamellæ, and united by interlamellar dissepiments, and in a longitudinal section the interlamellar dissepiments are exposed as strongly arched plates, the convexities of which are pointed upwards and outwards (Plate X., Fig. 1). They unite at their inner ends, and form a pseudo-columellarian line, and the floor of the calicular cavity is occupied by a conical boss, and the lamellæ are exposed extending from the inner ends of the septa, and converging upwards and inwards to the apex of the conical boss (Plate IX., Fig. 2). It will thus be apparent that, while *Lonsdaleia* has relationships with the genera *Thysanophyllum* and with *Lithostrotion*, it is separated from these genera by the possession of the lamellæ—interlamellar dissepiments in a tranverse section—and the floor of the calice is occupied by a conical boss, and the more massive form of the corallum. With our present knowledge, the nearest ally of *Lonsdaleia* is the

genus *Clisiophyllum* (Dana). Indeed, it may be said to form an intermediate group between *Clisiophyllum* on the one side, *Lithostrotion* on the other, and related to the genus *Thysanophyllum* by the possession of the zone of vesicular tissue that intercepts the extension outwards of the septal systems.

Lonsdaleia rugosa. (M'Coy.)

Plate IX., Figs. 1 and 2.

Specific Characters.—Corallum compound and in fasciculate masses. Gemmation is latro-calicular, and the young corallites emerge through the wall, and grow alongside of the parent, and in some instances they are fused together (Plate IX., Fig. 1, 1D, 1E, and 1F. The epitheca is stout, and there are irregular and broad annulations of growth. The calice is moderately deep, and its floor is occupied by an acute conical boss, formed of lamellæ, which extend inwards and upwards to the apex, and each is united by interlamellar dissepiments. The septa are lamellar, and of two orders, and their extension outwards is intercepted by a broad zone of irregular cellular tissue, and each is united by interseptal dissepiments, which are sparse. In Fig. 2 may be seen the different stages of development, from the simple cell, situated in the vesicular tissue near the periphery, and may be traced to the mature corallite. The longitudinal section exhibits the convex cells in the central area, the concave tabulæ in the intermediate (interlocular) area, and the irregular vesicular tissue in the outer zone.

Formation.—Lower carboniferous.

Locality.—Found at Boghead, Lesmahagow, Lanarkshire.

Lonsdaleia duplicata.

This species is of smaller dimensions, the septa extend considerably further outward towards the wall, and are therefore longer, and the interseptal dissepiment are more numerous, and in the earlier stages of development the centre is tabulate, and with further development the lamella are at first seen as lateral points, and which become enlarged as the corallite becomes more developed, and ultimately a conical boss is apparent. The corallites are usually free laterally, and grow side by side in compound fasciculate communities. This species is rare in Scotland.

Formation.—Lower carboniferous.

Locality.—Found at Glenmuirshaw Water, near Muirkirk, Ayrshire.

Lonsdaleia floriformis. (Fleming.)

Plate IX., Fig. 3.

This species is distinguished from all the other species of the genus by the fact that the corallites are always of smaller dimensions, and the walls are fused by lateral pressure, and is usually found in compact masses, and a portion of the septa extends to the wall, and is therefore nearly allied to some of the species of *Lithostrotion*. Indeed, the similarity is so great that it was regarded as belonging to that genus until M'Coy created the genus *Lonsdaleia*, with which it has closer affinities. It, however, may be regarded as having a more or less intermediate position between the genus *Lithostrotion* and that of *Lonsdaleia*, and therefore further illustrates the proposition that variation is universally apparent throughout the entire series, and that development induced by causes of a varied character has produced modifications which diverge in all directions, and which bridge and unite generic relations by almost imperceptible gradations.

Koninckophyllum. (Nicholson and Thomson.)

The genus *Lonsdaleia*, while it presents an intimate and intermediate relation to the genus *Thysanophyllum* and *Lithostrotion*, is more or less related to the compound forms of *Koninckophyllum*, by the possession of a central columellarian rod and the development being by latro-calicular gemmation, and therefore in compound fasciculate communities. It is, however, separated from the latter, from the fact that in the latter the central area is occupied by tabulæ, while in *Lonsdaleia* the central area is composed of lamellæ and vesicular tissue. There is, however, an intimate relation between the larger species of the genus *Lithostrotion* and that of the compound forms of *Koninckophyllum*. The latter, however, is always distinguished by the further extension inwards of the septa, and the more densely-developed interseptal dissepiments in the peripheral zone. It is, however, separated by the introduction of structural modifications

of a very important and fundamental character. In *Lithostrotion* the floor of the calice is more or less occupied by tabulæ with a central rod. In the genus *Köninckophyllum* there is introduced a series of radiating plates from the columella outwards, which are clearly seen to pass through a series of modifications, and ultimately to merge into lamellæ, and the interlamellar dissepiments are developed, and thus indicate and present structural characters which show clearly a series of transitions from between the more highly developed forms of *Lithostrotion*, and an intimate relation to the genus *Lonsdaleia* by, first, the compound fasciculate colonies, and, second, by the development of the lamellæ in the central area, and may thus be regarded as a central group which diverge in varied directions, and which can be shown to diverge into a genus, whose structural details are very dissimilar to either of the groups above referred to, which will be more fully referred to when I have occasion to notice the structural characters of the simple, as well as the compound forms of the genus *Köninckophyllum*, and which fall to be noticed with the genera whose structural details warrant us in regarding the series as belonging to the *Actinozoa*. Meanwhile, with our present knowledge, the compound form of *Köninckophyllum* may be regarded as possessing structural details which show clearly that modification is endemic, not only in species and genera, but also in families. In the great majority of the preceding genera we found the septal system developed and extending along the superior face of the tabulæ. In this and the preceding genus the septa extend more or less from the inferior to the superior extremity of the corallum, and therefore may be regarded as an intermediate series that unites the *Zoantharia rugosa* to that of the *Actinozoa*. In this, as in many of the groups, I am satisfied that other and more intimate forms will yet be discovered, which will unite them even more closely, and clearly show that modification and development is and has been the resultant of universal law.

ACTINOZOA RUGOSA.

The *Actinozoa* includes those groups in which reproduction is by ova that are developed in the mesenteric folds of the interlocular area, and which are ejected from the mouth, and when fully developed, remain simple and free, and secrete a continuous skeleton. The floor of the calice is closed in by septa, lamellæ,

interseptal and interlamellar dissepiments, and the septa and lamellæ extend uninterruptedly from the base to the superior extremity of the corallum, and are therefore essential. Those belonging to the carboniferous system include a variety of simple forms of an extremely varied character, and throughout the series the transitional tendencies are so constant and the variations so minute, that in many of them there is great difficulty in defining their classificatory position. Indeed, after years of careful observation, I have a large series of sectioned specimens that have not yet found a place as belonging to any definite genus. Those forms that I have grouped into genera and species present characters which seemed to me to warrant their classification. These genera and species are surrounded by varieties which are united by structural details of an extremely minute character. Many of these, if examined by themselves, present generic relations of a very pronounced nature, but, when compared with a series, even their generic relations becomes a matter of doubt. But in order that there should be some systematic ground plan, I have selected those forms whose structural details warrant their being classed as having generic relations, and that have central types which include forms that diverge in both directions, and their specific distinction upon their relative parts, and which include twenty-two genera. The generic characters I shall now describe, and note briefly a few of their specific relations, and, as far as my investigations will admit of, refer to the polymorphic tendencies of the different groups.

As pointed out at page 405, the genus *Heterophyllia* was more or less related to the genus *Lithostrotion*, by the fact that in *Lith. junceum* (Flem.) the septal system extended from the wall inwards. They then coalesced, and a portion of them extended in to the centre of the corallum, and their union gave rise to the columella—a structural detail which is characteristic of some of the species of *Heterophyllia*.

Genus HETEROPHYLLIA. (M'Coy.)

Generic Characters.—Corallum simple, tall, cylindrical, and tapering to a point near the base, and fluted, and some forms are twisted. The epitheca is stout, and in some forms there are irregular, broad annulations of growth. The calice is shallow, and the septa are everted, and at their inner ends the centre of the

calicular cavity is slightly depressed. The septa are lamellar, and extend from the wall to near the centre, where they coalesce into fasciculate groups, and the central septum in each fascicle extends inwards to the centre, and forms a pseudo-columella. The centre differs in the structural details in most of the species. The longitudinal section exposes in some species one, in others two, and in others three columellarian lines, united by minute transverse tabulæ, and there is a system of tabulæ on either side of the columellarian area, which are more or less convex, convexity pointing upwards and outwards; and at the outer margins they bend downwards and are attached to the wall, in some species, and in others rest upon minute vesicular tissue in the peripheral area. There is a septal fossula in the large varieties.

Heterophyllia grandis. (M'Coy.)

Plate X., Figs. 15, 15A, 16, and 16A.

Specific Characters.—Corallum simple, tall, cylindro-conical, and twisted. The epitheca is stout, and marked with flexuous longitudinal ridges, and broad, irregular annulations of growth. The calice is shallow. The septa are everted, and bend slightly downwards at their inner ends. In a transverse section, $3\frac{1}{2}$ lines in diameter, there are twenty-four septa, which are irregular in their extension inwards, and near the centre they coalesce and form fasciculate groups, and the central septum in each fascicle extends into the centre. There they coalesce and form a psuedo-columella, and each is united by interseptal dissepiments, which are minute near the periphery, and larger and fewer in number near the central area. The fossula extends into the centre of the calicular cavity.

The longitudinal section is triareal. The outer area is occupied with a narrow zone of minute convex vesicular cells, convexity inwards. The intermediate ("interlocular") area is occupied with broad convex tabulæ, which are united to the outer columellarian rods, and at their outer ends they bend down and rest upon the zone of vesicular tissue in the peripheral zone. In the central are three crenulate columellarian rods, and these are united by minute rectangular tabulæ.

Formation.—Lower carboniferous.

Locality.—Found at Charlestown, Fifeshire, in the shale that overlies the thick bed of limestone.

Heterophyllia Phillipsia. (Thomson.)

Plate X., Fig. 14.

This species is distinguished from the preceding by the dense zone of interseptal dissepiments in the peripheral zone, and the outer margins of the septa are much stouter, and the epitheca is much stouter, smooth, and there are shallow and broad annulations of growth and faint longitudinal ridges.

Formation.—Lower carboniferous.

Locality.—Found at Charlestown, Fifeshire, in the same horizon as the preceding.

Heterophyllia granulata. (Duncan.)

Plate X., Figs. 19, 19A, 19B.

This species is characterized by the stout, flexuous vertical ridges, and the dense granular epitheca, and in the longitudinal section the tabulæ are fewer in number, and the central (columellarian) area is not so broad.

Formation and Locality.—Same as the preceding.

Heterophyllia angulata. (Duncan.)

Plate X., Figs. 18 and 18A.

This species is distinguished from the preceding by the fact that it is never so stout. The longitudinal ridges are represented by fine lines; the epitheca is smooth; the tabulæ are not so numerous, and are concave. The central area is broader, and the interlamellar tabulæ are less numerous. Upon the whole, the structure is less dense.

Formation.—Lower carboniferous.

Locality.—Found in the dark shale that overlies the thin beds of limestone at Brockley, Lesmahagow, Lanarkshire.

Heterophyllia M'Coyi. (Duncan.)

Plate X., Figs. 21, 21A, 21B, and 21C.

This species is considerably smaller, and hexagonal. The longitudinal ridges are opposite each angle, and the septa converge

inwards from the angles of the wall and unite in fascicles of three, and the central septum of each fascicle extends inwards and unites in the centre of the corallum. The epitheca is smooth, and the ridges are indistinctly grooved.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire, and Cunningham Baidland, Ayrshire.

Heterophyllia Sedgwicki. (Duncan.)

Plate X., Figs. 17 and 17A.

The species is separated from the preceding by the possession of secondary septa. There are ten primary, and these alternate with an equal number of secondary septa. The corallum is cylindrical. The epitheca is smooth near the lower extremity, and there are sharp ridges near the apex. The septa extend to the wall, and there are no interseptal dissepiments. The longitudinal section exposes the sinuous columellarian lines and the angular tabulæ extending inwards and upwards to the columellarian area.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire, and Broadstone, Beith, Ayrshire.

Heterophyllia Lyelli. (Duncan.)

Plate X., Figs. 21, 21A, and 21B.

This species is separated from the preceding, its nearest ally, by the possession of a minute cylindrical tube extending from the inferior to the superior extremity of the corallum. The corallum is tall, flexuous, and hexagonal. There are six septa, which converge from the angles of the corallum and extend inwards to the circular tubular columella, and there are prominent costal ridges and minute pores along the crown of the ridges about half a line apart.

Formation.—Lower carboniferous.

Locality.—Found at Craigenglen, Campsie, Dumbartonshire, and Brockley, Lesmahagow, Lanarkshire.

Heterophyllia mirabilis. (Duncan.)

Plate X., Figs. 22, 22A, and 22B.

This species presents characters of a very marked nature. The corallum is tall and cylindrical, the ridges are delicate, and there are curved, hook-shaped process along the crown of the ridges, which, when disconnected, leave a large granule, and there is a minute depression in its centre. The base of the disconnected hooklets are round, and indicate a ball and socket arrangement. There are five septa, which converge from the wall. Four of them unite in the centre, and two of them coalesce before they reach the central area, and are bifurcate. The longitudinal section exposes a thin columellarian line, and there are rectangular tabulæ $\frac{1}{20}$ of a line apart. The wall is stout and smooth.

Formation.—Lower carboniferous.

Locality.—Found in Craigenglen, Campsie, Dumbartonshire, and Brockley, Lesmahagow, Lanarkshire.*

From the above brief description of the structural details of the genus, it will be apparent that in it there is presented characters of an unusually marked nature. The external aspects of the different species are unlike any other group that I am acquainted with, and therefore cannot be confounded with any other genus. In the structural details, however, there is presented characters which possibly indicate more forcibly the endemic tendency to variation than is found in any other group; and as species after species are compared, we not only find them specifically distinct in themselves, but we have also indicated the most palpable illustration of their disposition to divergence, clearly showing that

* I have introduced the eight species of *Heterophyllia* for the following reasons:—*First*, they are the only species of that genus that I have yet discovered; *second*, they are the specimens that Dr. P. M. Duncan, F.G.S., London, described in a paper communicated to the Royal Society by Professor Thomas H. Huxley, LL.D., F.R.S., 2nd May, 1867, and in consequence of the author omitting to state that I was not only the proprietor, but also the discoverer of these specimens, and that I had sent them to him for identification, and in consequence of my name not being associated with their discovery, considerable doubts were expressed regarding their authenticity, I therefore feel called upon to record the facts in order that no further doubts may exist.

the tendency of variation is to progressive development, which could only be induced by the innate tendency to variation in the tissue of the living animal. There are, however, structural details exhibited in the transverse sections which clearly indicate their dimorphic tendency. In the series the septal system is developed from the most simple character to those whose septa and interseptal dissepiments are of high value. I will now briefly summarise their character, and will thus be able to form an approximate estimate of their relationship.

(1) In *Heter. Phillipsi* the tabulæ are divided in the central area, and the interseptal dissepiments are dense, and indicate a remote relationship to the genus *Köninckophyllum.*

(2) In *Heter. grandis* the septa are in fasciculate groups, and the interseptal dissepiments are sparse, and thus indicate a near relationship to the genus *Fasciculophyllum*, afterwards to be noticed.

(3) In *Heter. Sedgwicki* the septa are of two orders. The primary septa extends inwards in fasciculate groups, and the central septum passes in to the centre, unites, and forms a pseudo-columella. The secondary septa are minute; each extends from the wall, and there are no interseptal dissepiments, and therefore present characters which have a close alliance to *Lithostrotion junceum.*

With these points of resemblance, there are the following differences to be noted in the structure of the forms respectively referable to *Köninckophyllum, Fasciculophyllum*, and *Lithostrotion.*

(1) The central area in *Köninckophyllum* is formed by the intersection of a system of transverse tabulæ with a vertical columellarian rod, and there is a dense broad zone of vesicular tissue, while in all the species but one—*i.e., Heter. mirabilis*—the central area is occupied by two and three columellarian lines, and the vesicular tissue is sparse. The calice in *Köninckophyllum* is deep, and sharply defined around the periphery, and the corallum is always more or less conical, and there is never costal ridges; while in *Heterophyllia* the calice is always shallow and everted, the vesicular tissue is sparse, and the corallum is tall and cylindro-conical, and there are costal ridges.

(2) The corallum in *Fasciculophyllum* is simple, the septa are more highly developed, and there are no costal ridges.

(3) In *Lithostrotion* the corallum is compound; gemmation is calicular, and therefore in dense fasciculate communities. The

calice is moderately deep, and the septa are developed along the superior face of the tabulæ, and therefore do not extend uninterruptedly from the base to the superior extremity of the corallum; while in *Heterophyllia* the extension of the septal system is uninterrupted from the lower up to the superior extremity of the corallum, and the tabulæ are formed by the interseptal dissepiments.

In addition to the extraordinarily varied internal structural details, the external markings are of themselves sufficient for any competent observer to warrant the acceptance of specific distinctions, which may be briefly referred to.

(1) In *Heter. mirabilis* the hook-like process, when dissociated, leaves on the crown of the costal ridges large prominent granules with a depression in the centre and about $\frac{2}{3}$ of a line apart, and the corallum is either cylindrical or sub-cylindrical.

(2) In *Heter. Lyelli* the crowns of the prominent costal ridges are marked by a series of minute depressions or pores, about $\frac{1}{2}$ of a line apart, and the corallum is hexagonal.

(3) In *Heter. Sedgwicki* the costal ridges are minute, sharp, and only developed in the upper extremity of the corallum.

(4) In *Heter. M'Coyi* the costal ridges are indistinctly grooved, and the epitheca is smooth.

(5) In *Heter. angulata* the costal ridges are represented by faint lines.

(6) In *Heter. granulata* the costal ridges are flexuous, and the epitheca is densely granular.

(7) In *Heter. Phillipsi* the epitheca is dense and smooth, and there are shallow and broad annulations of growth, the costal ridges being indistinct.

(8) In *Heter. grandis* the epitheca is smooth, the costal ridges are flexuous and numerous, and there are broad annulations of growth.

Upon the whole, while the above-mentioned distinctions appear of sufficient value to warrant the acceptance of the generic distinction of *Heterophyllia*, there are other modifications which might have been noticed; but I conceive that, from the structural details indicated, will induce the conviction that modification is endemic, that in this, as in all the previous groups, there is a persistent tendency to variation, and that modification has been more or less affected by either external conditions, or from an innate tendency in the tissue of the living animal that secreted these organic remains.

In tracing the relationships of these organic remains in an ascending and connected series, we are led now to consider what

connection there is between the genus *Köninckophyllum* (Nich. and Thom.) and the preceding genera, the transitional tendencies of which indicated that, with further development, or the discovery of other allied forms, we should be able to demonstrate more fully the principle that there is a correlation of both genera and species, and that varieties are but the lower links in the chain that binds the simple and the more complex forms into a united whole.

Genus KÖNINCKOPHYLLUM. (Thomson and Nicholson.)

Generic Characters.—Corallum simple or compound. The septa are well developed, but not reaching the centre, and united externally by numerous delicate dissepiments, which give rise to an exterior zone of dense vesicular tissue. The tabulæ occupy the central area, into which the septa are never continued, and are divided in two halves by a styliform columella. There is a septal fossula. In the compound forms gemmation is calicular, and in the simpler forms they are developed by ova. The epitheca is thin, and marked with fine encircling striæ, and there are annulations of growth. The calice is of variable depth—its margin is in some forms thin, in other species it is thick and everted; in the latter the calice is shallow.

In the centre of the calicular cavity is a small compressed columella, which, in those forms in which the transitional tendency is indicated, is more or less interrupted (Plate XI., Figs. 2, 2A, and 3A). During the earlier part of my investigations I was at a loss to understand whether this was due to any real want of continuity, or whether it was not caused by flexures of the corallum taking the columella at this place out of the line of section; but, after making sections of a large number of forms, I am induced to regard its aberrant aspect as indicating its endemic tendency to variation. The longitudinal section is triareal (Plate XI., Fig. 1A). The outer ("interseptal") area is occupied by a dense zone of convex cellular tissue, convexity pointing inwards and upwards, and arranged in oblique rows, the intermediate ("interlocular") area by loose convex cells, convexity pointing upwards and outward, and the central area by an irregular and closely-arranged tabulæ, which are more or less convex. The compact columella forms a distinct thin line, which, in typical species, extends from the base of the visceral chamber to the superior extremity, and is seen in the floor of the calice as a projecting point.

The septa are of two orders, and externally are united by

numerous close-set delicate dissepiments, which are sometimes rectangular, and in others finely anastomosing and reticulate (Plate XI., Figs. 1 and 2), which give rise to zones of cellular tissue, seen in the longitudinal section in the peripheral zone.

As regards the relationships of the genus *Köninckophyllum*, it may be said to be distinguished by characters of a marked nature. In some respects it is nearly allied to the large fasciculate varieties of *Lithostrotion*, and to some of the species of *Campophyllum* (such as *Camp. paracida*, M'Coy), but it is separated from the former by the possession of a dense zone of vesicular tissue, and the septa are more highly developed; and from the latter by the styliform columella in the centre of the central area, while it is thus generically distinct from those genera. In *Köninckophyllum* there is indicated a transitional tendency of a marked character. In those forms in which the columellariau rod is styliform there is no cause for reasonable doubt as to the validity of the genus. If, however, there is an extensive series of specimens sectioned transversely, it will be observed that there is an indication of the columellarian rod becoming elongated, which can be traced from a small oblong point, extending and becoming more and more elongated, till by its extension the central area is divided into two halves, and thus exposes a prominent central median plate, which becomes considerably elevated above the plain of the tabulæ, and thus merges and unites by gradations of an extremely minute character, and by the greater development of the central rod it emerges from the type character of the genus, and induced us to create the generic name of *Acrophyllum* of Thomson and Nicholson for the reception of those forms in which the central area is divided into halves, and in the transverse tabula of the central area is still a prominent character.

A few of the transitional tendencies are indicated in the following species:—

(1) *Köninckophyllum proliform* (Thomson and Nicholson).—In this species the corallum is compound and in fasciculate communities, and is therefore more or less allied to the genus *Lithostrotion*. It is separated by the more highly-developed septa and the denser zone of vesicular tissue in the peripheral area, and may be regarded as the species whose relations are intermediate between the latter and the former genus.

(2) In *Köninck. magnificum* (Thom. and Nich., Plate X., Figs. 1 and 1A) is represented the type of the genus.

(3) In *Köninck. interruptum* (Thom. and Nich., Plate XI., Figs. 3 and 3A) is represented the innate tendency to variation which, with further modification, would merge into the typical aspect of *Köninckophyllum*, and may be regarded as being an intermediate form between *Campophyllum* and that of *Köninckophyllum*.

(4) In *Köninckophyllum*, sp. ?, (Plate XI., Figs. 5 and 6) in which there is exhibited in the floor of the calice the first indication of the divergent character of the group. In Fig. 6 the columella is divided by a median plate, and is more or less cruciform. In Fig. 5 there is a further extension of the tendency to modification.

(5) In *Köninck. ritiforme* (Thom. and Nich., Plate XI., Figs. 2 and 2A), the structural details of the central area are considerably more varied, and demonstrates clearly the endemic tendency to variation, which, with further development, will merge into and unite the group to the genus *Histeophyllum microphyllum* (Thomson, Plate XI., Fig. 7). Indeed, did space permit, I could have introduced a large series of engraved forms, in which could be traced not only the most minute transitions from the former into the latter genus, but also could have shown, by the extension of the columella, a series of transitions of an extremely minute character, and to merge into the genus *Acrophyllum* (Thom. and Nich.). In Plate XI., Fig. 9, I have introduced an example of one of those varieties, in which the central plate is considerably extended, and in which there are marked indications of further modifications, by the presence of more or less reticulate structure in the central area; and I might have shown, by the introduction of other varied and intermediate forms, in which the further development of that part is seen to be by almost imperceptible gradations, until there is developed a central plate, which stretches across the total diameter of the central area of the corallum (Plate XI., Fig. 12). In another variety—*i.e.*, *Köninckophyllum radiatum* (Thom. and Nich.)—there are a series of minute plates, which radiate from the columella in all directions, and thus indicate a further modification, and a divergence into another group, in which lamellæ are present in the central area. Their form and arrangement is regarded to be of generic importance. On the whole, the genus *Köninckophyllum* may be regarded as polymorphic, and which have divergent relationships, which merge and unite groups in varied directions—modifications induced by either the endemic tendency to variation, or which have been affected by the altered

conditions of the surroundings. Meanwhile, I will endeavour to trace the relationship that exists between the genus *Köninckophyllum* and that of the genus *Acrophyllum*.

Genus ACROPHYLLUM. (Thomson and Nicholson.)

Generic Characters.—Corallum simple, turbinate, or cylindro-conical. The epitheca is thin, with numerous encircling striæ and annulations of growth. The septa are of two orders. The primary extend inwards fully a third of the total diameter of the corallum, and the secondary septa are hardly recognizable in the dense vesicular tissue of the peripheral zone. A fossula is present. The longitudinal section exposes the triareal arrangement of the structural details. The outer ("interseptal") area consists of convex vesicular tissue—convexity pointing inwards and upwards, and arranged in oblique rows; the intermediate ("interlocular") area is closed in by large convex cells—convexity pointing upwards and outwards; and the central area is occupied by irregular tabulæ, which are more or less sharply bent upwards and inwards, and at their inner ends they ascend and form the stout columella, which is more or less bilamellar, which, in a transverse section, divides the tabulæ of the central area into two halves, and is exposed in the floor of the calicular cavity as a prominent ridge. The calice is of variable depth.

The general characters of the internal structure of the forms I have grouped under the name of *Acrophyllum*, present a close resemblance to those which properly belong to *Köninckophyllum*, but they are nevertheless separated by structural details sufficiently distinct and easily recognizable to warrant their being placed in a section by themselves. The species of *Acrophyllum* agree with those of *Köninckophyllum* in their triareal structure, as shown in the longitudinal section. In both there is an outer area of numerous minute convex vesicles—convexity pointing inwards and upwards, and arranged in oblique rows; an intermediate area formed of irregular convex cells, and pointing outwards; and the central area is formed by vesicular tabulæ, which are more or less elevated centrally and intersected by a vertical columella. In both groups we find a striking similarity in the arrangement and development of the septa. The primary extend from the wall usually for a third of the total diameter of the corallum, and each are lamellar internally, but become more delicate as they pass outwards, and are

intersected by the dense zone of interseptal dissepiments; while those of the second cycle are hardly recognizable. With these points of resemblance there are the following differences to be noted in the forms respectively referable as allied to the genus *Acrophyllum*:—

(1) In *Koninckophyllum* there is a compressed median rod, and the floor of the calice is occupied by tabulæ, which are but slightly elevated near the columella, while in the genus *Acrophyllum* the columellarian rod is in the form of a vertical plate, and more or less lamellar, which extends across the total diameter of the central area (Plate XI., Figs. 12, 13, 14, and 15); being formed by the union of the acutely-elevated tabulæ at their inner margins, and present in the floor of the calice an elevated ridge; and the tabulæ bends downwards to the inner ends of the primary septa.

(2) *Acrophyllum* has not yet been found in fasciculate masses. It will thus be apparent that the genus *Acrophyllum* has near relations to *Koninckophyllum*. Yet I believe it possesses characters sufficiently distinct to warrant it being regarded as a separate genus, and which is here represented by the following species:—

Acrophyllum Billingsi. (Thomson.) Sp. nov.

Plate XI., Fig. 12.

Specific Characters.—Corallum simple, cylindro-conical, moderately tall, and curved. The epitheca is thin, with delicate encircling lines, and broad irregular annulations of growth. The calice is shallow and slightly everted; and in the centre of its floor there is a prominent median ridge, which bisects the tabulate area, and is seen in the transverse section extending from the inner margin of the primary septa, extending to the opposite side of the tabula, and attached to a sub-semicircular plate at the inner margin of the fossula. Along the lateral margin there is a series of convex plates—convexity pointing downwards—and on the opposite side the convex plates point outwards, which are the cut edges of the down-curved tabulæ, and there are faint indications of lamellæ. The fossula is small, and three of the primary septa extend into it, which are about a line shorter than the others. The septa are of two orders. The primary are lamellar for two-thirds of their length from their inner margins, and thin and slightly flexuous outwards to the periphery, and these alternate with an equal number of secondary septa. The latter extend

inwards for half the length of the primary, and each are united by more or less angular interseptal dissepiments, which are dense in the outer zone, and few and rectangular in the interlocular area. There are interlamellar trabicula. There are forty-eight primary, and an equal number of secondary septa.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire, in shale about three feet above thick beds of limestone.

This may be regarded as a type species of the Scottish varieties, and I have great pleasure in naming it in honour of the late eminent Canadian palæontologist.

Acrophyllum. Sp. (?).

Plate XI., Fig. 9.

This species is distinguished by the broader tabulate area. The median plate stops short of the total width of the tabulate area, The fossula is larger. The primary septa are lamellar for half their length, and the secondary septa extend inwards for two-thirds of the total length of the primary septa, and the vesicular tissue is denser than in the preceding species, which may be regarded as being an intermediate species between the genus *Köninckophyllum* and that of *Acrophyllum.* It, however, possesses structural details more closely allied to the latter, and therefore must be placed in that group.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire, in the same horizon as the preceding.

Acrophyllum. Sp. (?).

Plate XI., Figs. 13 and 13A.

This is separated from the preceding by the median plate being stouter, the further extension of the septa inwards, and there is indications of the development of lamellæ. The primary septa are stout and lamellar for three-fourths of their length from their inner ends, and the secondary septa are short. The interseptal dissepiments are rectangular, and the fossula is smaller.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Acrophyllum. Sp. (?).

Plate XI., Figs. 14 and 14A.

This species is distinguished by the further extension of the primary septa inwards. They are stouter, and there is an enlargement at their union with the secondary septa, and the interseptal dissepiments are rectangular and less dense. The fossula is small, and there are indications of lamellæ, which extend from the inner ends of the primary septa to the median plate, and the median plate does not quite extend to the inner ends of the septa. On the whole, this species indicates a transitional condition, and may be regarded as a variety which, if more fully developed, would merge into the genus *Dibunophyllum.* Fig. 14A is a section taken from fully $\frac{4}{1}$ of an inch from the base.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Acrophyllum dendriformis. (Thomson.) Sp. nov.

Plate XI., Fig. 15.

This species differs from the preceding by the possession of a fusiform median plate, the dendriform aspect of the primary septa, the small central area, and the presence of a system of plates, which unite the inner ends of the primary septa with the sub-tabulate central area and cellular tissue on one side of the median plate, and on the other side the union of a convex plate. On the whole, while this species clearly indicates a transitional tendency into the genus *Axophyllum*, yet it has the characteristic of *Acrophyllum* clearly developed.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

It will thus be evident that the genus *Acrophyllum* possesses structural characters which indicate clearly polymorphic tendencies. Indeed, if I had referred to the large series of varieties that are in my cabinet, I could at least have occupied the whole plate with their illustrations. I have, however, selected a few typical forms, which show the divergent character of the genus, and will shortly refer to the transitional tendency of the group.

(1) *Acrophyllum*, sp. (?), Fig. 9 represents a variety which,

although the structural details are present in a typical species of *Acrophyllum*, yet its relationship is more nearly allied to that genus than it is to *Koninckophyllum*, by the greatly more elongated median plate, and it may therefore be regarded as an intermediate form between those genera.

(2) *Acrophyllum Billingsi*, Fig. 12. This may be regarded as a clearly-defined species of the genus, and need not be further referred to.

(3) *Acrophyllum*, sp. (?), Figs. 13 and 13A, is another distinct species.

(4) *Acrophyllum*, sp. (?), Figs. 14 and 14A. In this species there is the generic character in the possession of the median ridge. There is, however, structural details developed in the central area that indicate a transitional tendency to merge into the genus *Dibunophyllum*, and it may be regarded as an intermediate form.

(5) *Acrophyllum dendriformis*, Fig. 15. The extension of the median ridge, and the more or less tabulate area, clearly unite this variety to the genus. In the presence, however, of the cellular tissue on the one side of the central area, and the possession of the system of plates that extend from the inner ends of the primary septa and unite, the structural details that are exhibited in the central area clearly point to a considerable modification in the structural details of the central area, which, if slightly more developed, would be regarded as a variety of the genus *Axophyllum* (E. and H.).

As regards the relationships of the genus, *Acrophyllum* may be said to be distinguished by characters of a distinct nature. I have referred to its near alliance to the genus *Koninckophyllum* on the one hand; and some of the species possess aberrant structural details which clearly point to its divergent nature, and indicate its transitional tendency, and its merging into *Dibunophyllum* on the one hand, and, on the other, a near affinity to *Axophyllum*, and thus abundantly testifies to the polymorphic relations, and is a further testimony to the proposition that the plasticity of animal tissues were extremely mobile and susceptible of the faintest impressions, and each affected organ secreted a counterpart of the altered tissue, and thus enables us to realise how modification was induced, and, with further development, how variation was transmitted from group to group.

In some of the species, however, of *Koninckophyllum* there is another modification of the columella in the type species. The

normal condition of the columella is a styliform compact and compress medium rod. There are varieties in which the columella is formed of convex plates, convexity pointing outwards. Plate XI., Fig. 1 exhibits the first beginning of that modification. There are other forms which more fully illustrate that transitional tendency, and which indicates a further divergence in a different direction, and point to the development of a tubular columella; and thus indicates a more or less remote relationship to the genus *Cyathaxonia*. The generic relations of that genus I shall now shortly refer to.

Genus CYATHAXONIA. (Michelin.)

Generic Characters.—Corallum simple, turbinate and cylindro-conical, and more or less curved or twisted. The epitheca is of variable thickness, and there are annulations of growth. The calice is variable in depth, and exhibiting in the centre of its floor a more or less conspicuous styliform columella. The septa are of two orders. The primary septa extend inward to the columella, and the secondary septa are considerably shorter. The central area is occupied by the styliform columella, which, in a transverse section, is seen to be formed of minute cellular tissue, and in others it is tubular. The intermediate ("interlocular") area is composed of the inner margins of the primary septa, and there is no interlocular tabulæ; and the spaces are open from the superior to the inferior part of the corallum. The outer ("interseptal") area is occupied by the septa. The secondary septa are usually short, and near the periphery they are united by sparsely-developed interseptal dissepiments. There is a septal fossula.

The longitudinal section exhibits the styliform columella in the centre of the corallum, and formed by sparse vesicular tissue in some forms, and in others by a cylindrical tube. The intermediate ("interlocular") area is usually open for three-fourths of the total length of the corallum, and at the lower extremity the primary septa are seen to curve inwards, and become attached to the columella in the centre of its floor. The outer ("interseptal") area is occupied with sparsely-developed convex interseptal dissepiments, convexity inwards.

The genus *Cyathaxonia* was established by Michelin in 1846, for the reception of a group of corals, which in some respects are remotely related to the genus *Köninckophyllum* of Thomson and

Nicholson on the one hand, and on the other to the genus *Axophyllum* of Edwards and Haime (Plate XI., Figs. 8A, 10, and 11). It is, however, separated from these genera by the presence of a deep calice and tall styliform columella, and by the union of the primary septa to the columella near the lower extremity of the corallum: with one exception, *i.e.*—Plate X., Fig. 26—which may be regarded as indicating an intermediate and passage form into the genus *Cyclophyllum;* while in *Köninckophyllum* and *Axophyllum* the primary septa never reach the columella, and are intersepted by a system of more or less remote and convex tabulæ.

In the external aspect of some of the forms they present a close resemblance to the young forms of *Clisiophyllum* of Dana (Plate X., Fig. 28); but they are separated by characters sufficiently distinct and easily recognizable to warrant them being grouped with the genus *Cyathaxonia.*

As regards the relationship and classificatory position of *Cyathaxonia,* an examination of the structural details leaves no doubt as to the singularly-pronounced structural characters of the genus; while it may be regarded as being remotely related to *Köninckophyllum* by the possession of a more or less cellular columellarian rod. In the former, however, a similar structural character is simply foreshadowed in the lateral convex plates around the styliform columella, and in *Axophyllum.* In the latter the columella is occupied by a series of more or less large cellular tissue (Plate XI., Fig. 10), and in other forms there is a compact central rod in the centre of the cellular tissue, and in both genera the septa never penetrate the central area and become attached to the columella. Though there is thus a more or less near relation between these diverse groups, in each, however, there are central types distinctly pronounced in their generic characters, and in each group there are divergent forms which merge and pass into other allied genera. While there is thus indicated transitional relationships in the genera referred to, which leave no doubt as to their true generic position, in *Cyathaxonia,* however, some portion of the septa always extends into and is united with the columella. *Cyclophyllum* is indicated in one species by a minute depression or cup in the centre of the columella (Plate X., Fig. 26), and thus shows a divergent character in another direction, and indicates that, with further modification and the greater development of the central area, the generic characters would become obsolete and

merge into the *Diplocyathophyllidæ*, and more or less approximate to the structural characters of *Aulophyllum*.

I will now briefly refer to a few of the species. For further details and a greater variety of illustrations, I have to refer to my paper, published in the Society's *Proceedings* in 1877.

Cyathaxonia cornua (of Köninck.).

Plate X., Fig. 29.

Specific Characters.—Corallum simple, conical, cylindro-conical, and curved, and some forms are adherent upon the spines of *Producta*. The epitheca is thin, and there are irregular and shallow annulations of growth. The calice is circular and deep. The septa are well developed, and at the interlocular area they project and contract the width of the calice for fully half its depth. There are eighteen primary, alternating with an equal number of secondary septa, and there are granulations along the face of each septum. The fossula is small, and one of the primary septa extends half the length of the others into it. The columella is tall, prominent, and conical, and in a transverse section is more or less cellular near the base, and thus indicates a relationship to *Axophyllum*.

Height of corallum, $4\frac{1}{2}$ lines; diameter of calice, $2\frac{1}{2}$ lines.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham-Baidland, Dalry, Ayrshire.

Cyathaxonia domiformis. (Thomson.)

Plate X., Fig. 28.

This species is distinguished by the dome-formed columella, and resembles some of the young forms of *Clisiophyllum*. It, however, differs from that genus in the prolongation of the primary septa to the centre of the corallum, while in *Clisiophyllum* the primary septa never extend into the central area, and the columellarian area is always occupied by a system of independent lamellæ.

Cyathaxonia Newburyi. (Thomson.)

Plate X., Fig. 24, 24A, and 24B.

This species is distinguished by the broad compressed columella,

and may be regarded as having indications of a relationship more or less varied, and points to its connection with *Köninckophyllum* by its styliform columella. It differs, however, from that genus by the fact that the primary septa are attached to the stout columella.

Formation.—Lower carboniferous.

Locality.—Found at Cunningham-Baidland, Dalry, Ayrshire.

Cyathaxonia cyathaminuta. (Thomson.)

Plate X., Fig. 26.

This species is separated from all the other species of the genus by the presence of a small central cup in the crown of the columella, which may be regarded as indicating its transitional tendency, and suggesting its mergence into and uniting the genus *Aulophyllum.*

From the above brief reference to the divergent character of the species of this genus, it will be apparent that in this group, as in all the preceding groups, its polymorphic tendencies are more or less clearly indicated. Yet I am satisfied, if my opportunities would admit, and that a greater number of these small forms that indicate a family relationship were sectioned, other connecting species would be discovered that would more closely unite not only the genera referred to, but would show that its divergent character had a more widely-distributed relationship than has yet been referred to; and would further demonstrate the belief that deferentiation is and has been one of the silent factors of immutable law; and that modification, even in microscopic proportions, has been innate in the most delicate structural tissue of the animal, which, with increased development, has abridged and enlarged their structural characters—a counterpart of which is now more or less found in their sclerodermic skeletons.

In the presence and position of the conspicuous columella in the centre of the corallum, and from the fact that some of the septa stop short of that part of the corallum, there is indicated a divergent character of another aspect, and which was referred to at page 99, when I pointed out the structural details of the genus *Phillipsastrea.* In one of the species of that genus we found that one of the septa extended inwards and upwards, and curved, folded over, and rested upon the opposite half of the tabulæ, and in its

floor exhibited a clavate columellarian protuberence, and thus indicated a transitional tendency to merge into a group, in which the extension of a septum in a more or less exposed clavate form induced M. Edwards and J. Haime to establish the genus *Lophophyllum* for their reception.

Lophophyllum. (Edwards and Haime.)

Generic Character.—Corallum simple, conical, and curved. The epitheca is stout. There are longitudinal ridges, encircling lines, and shallow and irregular annulations of growth. The calice is deep and circumscribed by the extension of the septa inwards to near the columella; they then bend sharply downwards to variable depths, and the floor is occupied by tabulæ, which extends outwards into the interlocular area, and the inner ends of the primary septa intersect the tabulæ for a greater or less distance in the different species. The septa are lamellar and of two orders. The primary septa are irregular in their extension inwards—some of them to near the columella; others stop short at about a fourth of the total diameter of the corallum, and on the curved or ventral side one of the septa extends into the centre of the calicular cavity, and at its inner end is more or less clavate in some forms, and in others it is not so formed. In some species the septa are united near their inner ends into a fasciculate group, and the central septum of each fascicle extends further inwards. In a corallum four lines in diameter there are twenty-four primary septa, and these alternate with an equal number of minute secondary septa, which in some forms are represented by large pointed granules. A fossula is present.

The longitudinal section is triareal, the central area is occupied with the columella, which intersects the tabulæ. The tabulæ are rectangular, and extend outwards from the columella, and near their outer ends they bend downwards and form the floor of the interlocular area, and the interseptal area is occupied by convex cellular tissue convexity pointing inwards.

The genus *Lophophyllum* possess characters of an unusually distinct nature, and may be regarded as a central group, which diverge into the genus *Cyathaxonia* on the one side, and indicate a transitional tendency into another remarkable group which I propose to designate *Fasciculophyllum*. In order that that relationship

may be better understood, I will briefly refer to the specific distinctions of a few of the species.

Lophophyllum parvulum. (Thomson and Nicholson.)

Plate X., Figs. 2 and 2A.

Specific Characters.—Corallum simple, small, cylindro-conical, and curved. The epitheca is stout, and marked with longitudinal ridges, crenulate encircling lines, and shallow irregular annulations of growth. The calice is circular and deep. The septa are of irregular length. A portion of them extend inwards to near the centre of the calicular cavity, and curve sharply downwards to the floor of the deep fossa, and another portion is considerably shorter. A septum extends into the centre, which is clavate, and near its inner end, half-a-line below its upper boundary, there is a semicircular expansion, exposing in each side a thin projecting plate, which becomes stout and folds round the inner margin of the clavate columellarian protuberance, resembling a miniature saddle or cushion. There are twenty-four primary septa, alternating with an equal number of minute secondary septa. These fold and become attached to the primary septa. The interseptal dissepiments are sparse. The septal fossula is large, a septum of shorter length extends into it, and there is a deep depression of the tabulæ at the inner end of the fossula.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

This species is readily distinguished from all the varieties of the genus by the pulvate termination of the septal columella and the greater extension inward of a number of the septa.

Lophophyllum reticulatum. (Thomson and Nicholson.)

Plate X., Figs. 1 and 1A, 4 and 4A.

This species is distinguished by the greater development of the interseptal dissepiments and more limited extension of the septa inwards, and one of the septa extends inwards and unites with the clavate columella. In a corallum four lines in diameter there are twenty-four primary septa, whose extension inwards is irregular, and these alternate with an equal number of minute secondary

septa; and the fossula is large, and two of the primary septa extends into it about half the length of the others.

Formation.—Lower carboniferous.

Locality.—Found at Shields, East Kilbride, Lanarkshire.

Lophophyllum eruca. (M'Coy.)

Plate X., Figs. 3 and 3A.

This species differs from the preceding by the delicate septa, and interseptal dissepiments, and by the fact that the columellarian septum is never so stout, and is much less clavate. Indeed, in some species the clavate aspect is totally wanting, and the fossula is indistinct.

Formation.—Lower carboniferous.

Locality.—Found at Auchenskeoch, Dalry, Ayrshire.

Lophophyllum intermedium. (Thomson.) Sp. nov.

Plate VI., Figs. 27 and 28.

Specific Characters. — Corallum simple, cylindro-conical, and curved. The epitheca is stout, and marked with encircling lines and shallow annulations of growth. The calice is moderately deep. The septa are irregular, and unite into fasciculate groups, and the central septum extends inward, several of them being united to the columellarian septum, while the secondary septa are hardly recognizable. The interseptal dissepiments are sparse, and the columellarian septum terminates as a tubercular protuberence. The fossula is indistinct.

Formation.—Lower carboniferous.

Locality.—Found at Shields, East Kilbride, Lanarkshire.

It will thus be apparent that in this genus there are represented structural details that clearly indicate divergent conditions, and which consist of—(1) In *Loph. purvulum* the recurved process at the inner end of the columellarian septum is foreshadowed in one species of *Phillipsastrea*. It, however, differs from that genus by the fact that it is a simple coral, and never found in compound

masses, and the septa are always encircled by a wall, while in *Phillipsastrea* the septa are confluent, and there is never a wall. (2) *Lophophyllum eruca.* The septa are never so stout, and the clavate aspect of the columellarian septum is scarcely recognizable. The septa are more irregular in their arrangement, and upon the whole the structural details are more delicate. (3) *Loph. reticulatum* may be regarded as typical of the genus. (4) *Loph. intermedium* indicates a transitional tendency by the fasciculate arrangement of the septa, and shows clearly its divergent character and its alliance to the genus *Fasciculophyllum.* It is, however, separated from the genus by the possession of, and the extension inwards to the centre of the columellarian septum, and thus the structural characters of *Lophophyllum* predominates; and therefore we can only regard such forms as diverging species, and as varieties between the genus *Lophophyllum* on the one hand, which merge and unite the group into that of the genus *Fasciculophyllum*, and thus adds additional testimony to the endemic nature of the animals whose skeletal frame is presented in varied and divergent sclerodermic organic remains. This group has more or less intimate relation to *Köninckophyllum* on the one hand and to *Axophyllum* on the other. The latter genus, therefore, falls to be examined, in order to know wherein that relationship consists.

Genus AXOPHYLLUM. (Edwards and Haime.)

Generic Characters.—Corallum simple, turbinate, and curved. The epitheca is of variable stoutness, and marked with encircling lines and annulations of growth. The calice is shallow, and the centre of its floor is occupied with a styliform columella, and surrounded by more or less spirally-twisted lamella, which occupy the space between the inner ends of the primary septa and the styliform columella, and are seen in the floor of the calice to be more or less concave around the columellarian rod. The septa are of two orders. The primary are lamellar, and there are interlamellar trabeculæ. The primary are intersepted at their inner ends by the structural details of the columellarian area. The secondary septa are minute, and in some species are hardly recognizable in the dense zone of vesicular tissue they intersect. The interseptal dissepiments are numerous in the outer zone and sparse in the interlocular area. A fossula is present.

As regards the relationship of the genus *Axophyllum*, a careful examination of the structural details leaves no doubt that there is a combination of characters which, while the generic structure is clearly indicated in such forms as *Axophyllum expansum* (E. and H., Plate XI., Figs. 8 and 8A), may be regarded as the type of the genus. In other varieties of the genus there is, however, presented divergent characters, which point to its alliance with other groups, and which may be traced passing from the genus *Köninckophyllum* into that of *Axophyllum*, and to merge and become united to the genus *Clisiophyllum*. This will be better understood by comparing the structural details of the three forms I have selected from many others to illustrate my observations.

Axophyllum expansum. (Edwards and Haime.)

Plate XI., Figs. 8 and 8A.

Specific Characters.—Corallum simple, and extremely turbinate. The epitheca is thin, and marked with minute encircling lines and shallow annulations of growth. The calice is broad, shallow, and everted. The septa extend inwards, and are intercepted by a system of more or less spirally-arranged lamellæ, which occupy the central space, and which is bisected by a styliform columella. In a transverse section (Fig. 8A) the primary septa are stout, flexuous, and lamellar, and there are interlamellar "trabeculæ." The secondary septa are minute, and each is united by rectangular interseptal dissepiments, which are numerous in the interseptal area and remote in the interlocular area. The fossula is moderately large, and a plate from the central area extends into it.

Height of corallum, 1 inch; diameter of calice, 1 inch 7 lines. The section represented in Fig. 8A is taken half an inch from the base.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Axophyllum. Sp. (?)

Plate XI., Fig. 10.

This species differs from the preceding by the presence of a cellular cylindrical columellarian rod, and the area between the

columella is occupied by a system of more fully-developed lamellæ. They, however, do not extend into the columella. The primary septa are more delicate in the outer area, and the secondary septa extend considerably further inwards. The zone of interseptal dissepiments is greatly more dense, and the fossula is larger, thus indicating a more or less near relation to the genus *Cyathaxonia* by the possession of the cellular cylindrical columellarian rod. It, however, differs from that genus in the possession of a series of aborted lamellæ that extend from the inner ends of the primary septa inwards to near the cylindrical columella, while in *Cyathaxonia* the septal system is united to the cylindrical columella at the bottom of the deep calice.

Axophyllum. Sp. (*l*)

Plate XI., Fig. 11.

This species is recognized by the circumscribed central area, the sparse development of the lamellar details between the inner ends of the primary septa, extending inwards to the loose cellular columella, and the columella is greatly elongated, and formed of convex plates, convexity pointing outwards, and may therefore be regarded as an intermediate or passage form between the genus *Köninckophyllum*, uniting the latter to the genus *Axophyllum*, and thus indicates the polymorphic character of the group, and which point to (1) *Axop. expansum* which may be regarded as typical of the genus. (2) *Axop.* (Fig. 10) is separated from the former by the possession of a cellular cylindrical columellarian rod, and thus indicates its relationship to the genus *Cyathaxonia*, and thus exhibits its divergent character in another direction, which, with further development, would merge into the genus *Aulophyllum*. The latter, however, differs from *Axophyllum* in the larger columellarian tube and its floor is formed by rectangular tabulæ.

Upon the whole, while those genera are more or less related by the presence of the columellarian rod, yet, from the above, we realize that that relationship is simply indicated, that each possesses structural characters that unite them to their own individual groups, and that while each group presents divergent characters, yet in each there is clearly pronounced an individuality which can at all times be readily recognized. In each we have exemplified their innate tendency to variation, and each modification illustrates the latent principle, that differentiation is

the resultant of the mobility and plasticity of the tissues of the living animals that fabricated those organic remains. When referring to the structural characters of the genus *Acrophyllum*, I stated that in certain species of that group there were indications of modification, and that there were forms that presented transitional tendencies which indicated their mergence and relation to the genus *Dibunophyllum* (Thomson and Nicholson), which in a connected series falls now to be considered.

Genus DIBUNOPHYLLUM. (Nicholson and Thomson.)

Generic Characters.—Corallum simple, turbinate, or conocylindrical. The epitheca is usually thin, and there are encircling lines and annulations of growth. The calice is of variable depth, exhibiting in the centre of its floor a round eminence, which is slightly raised above the inner ends of the primary septa, and is divided into two equal halves by a distinct longitudinal mesial crest. The calicine eminence is formed by a system of vertical lamellæ, which are united by interlamellar dissepiments, and attached to the inner ends of the primary septa by sub-convolute plates, but are altogether independent of either the septa or lamellæ. These vertical lamellæ appear on the surface of the calicinal boss as so many ridges, which radiate from the margin of the central area to the sides of the mesial crest.

The septa are of two orders. The primary are lamellar, and there are interlamellar "trabeculæ." The secondary septa are short and hardly recognizable in the dense vesicular tissue they intersect, and each is united by more or less angular interseptal dissepiments, which are dense in the outer interseptal zone and sparse and rectangular in the interlocular area. A fossula is present. The longitudinal section (Plate XII., Fig. 2B,) is triareal, exhibiting the median rod, and the interlamellar dissepiments are more or less concave near the centre, and convex near the outer margin of the central area—the space between the inner ends of the septa and the outer margin of the lamellæ, or "intermediate" area, being occupied by an irregularly-disposed system of plates; and the outer ("interseptal") area occupied by a broad zone of convex cells, convexity pointing upwards and inwards, and arranged in oblique rows.

In the general features of their internal organization, the forms which belong to the genus *Dibunophyllum* present a near

relation to those which properly belong to the genus *Clisiophyllum*, (Dana); and in the possession of the median plate it is closely allied to the genus *Acrophyllum;* but they are nevertheless separated by characters sufficiently distinct to warrant them being placed in genus by themselves.

Firstly. The calicinal boss is formed of vertical lamellæ, and united by interlamellar dissepiments, and it is divided in two halves by a medium ridge; while in *Clisiophyllum* the boss in the floor of the calicular cavity is conical, and the lamellæ converge inwards from the outer margin of the conical eminence to the styliform columellarian rod in the centre, and in the summit of the conical boss. Hence the great difference as to the appearance presented in the calice of these two groups. In *Clisiophyllum* there is a tent-shaped or conical calicinal boss, the sides of which are marked by spirally-twisting or straight ridges, which are the free edges of these vertical lamellæ, and radiating from the margins to the summit of the boss. In *Dibunophyllum*, on the other hand, we find a low, rounded calicinal boss, which is divided into two equal halves by a median ridge, to the sides of which are attached the radiating ridges representing the free ends of the vertical lamellæ. In both genera, however, it is to be remembered that the vertical lamellæ of the central area are not continuations of the primary septa, but are independent of these structures, and are only connected with them by the intervention of a system of subconvolute plates. The tabulæ of the central area in *Dibunophyllum* are more or less elevated towards the middle line, as they are in *Clisiophyllum;* but they are concave, whereas in the latter they are convex, convexity pointing upwards and outwards.

Secondly. The intermediate, or "interlocular" area, and in the external area, the "interseptal" area, the characters of which are similar in *Clisiophyllum* and in *Dibunophyllum*. Indeed, in all other respects the structural details are more or less similar in each; but being satisfied that it is alone in the central area that we can rest generic distinction, and from the fact that in those genera the boss in the centre is so markedly different, their generic distinction is of a very marked character.

Thirdly. There falls now to be noticed the distinctive characters of the genus *Acrophyllum* and of *Dibunophyllum*. In the former the calicinal boss is divided by a median ridge as in the latter. In the latter, however, as we have seen, there is a system of vertical lamellæ which converge inwards from the inner margins of the

primary septa and are united by interlamellar dissepiments; while in the former the median plate bisects the tabulæ of the central area, and the lamellæ are only foreshadowed by the presence of minute radiating plates, and developed on the superior face of the tabulæ; and the structural details of the outer ("interseptal") area are usually more dense in *Acrophyllum* than in *Dibunophyllum*. Upon the whole the generic characters are distinct and easily recognized in each.

Dibunophyllum splendens. (Nicholson and Thomson.)

Plate XII., Fig. 1.

Specific Characters.—Corallum simple, cono-cylindrical, and of large size. The epitheca is thin, with encircling stria and annulations of growth—the central area occupying somewhat less than a third of the total diameter. The radiating vertical lamellæ are disposed with great regularity on both sides of the mesial partition; and the interlamellar spaces are occupied with close-set curved dissepiments, representing the cut edges of the concave tabulæ. The septa are numerous; there are seventy-eight primary, and these alternate with an equal number of secondary septa, which are minute, and hardly recognizable in the dense zone of vesicular tissue they intersect. The fossula is small, and two of the primary septa, of shorter length than the others, extend into it.

Formation.—Lower carboniferous.

Locality.—Found at Gateside, Beith, Ayrshire.

Dibunophyllum M'Chesneyi. (Nicholson and Thomson.)

Plate XII., Figs. 2, 2A, and 2B.

This species is readily distinguished from the preceding by the less regular structural details in the central area. The septa are not so numerous, and the median ridge stops short of the outer margin of the central area, and may thus be regarded as pointing to a transitional tendency. Indeed, I might have introduced a large series of illustrations, showing the gradual diminution of the median ridge on the ventral side, and passing by minute gradations into the genus *Aspidophyllum*, its nearest ally. Fig. 2 shows the arrangement of the structural characters of the central area.

Dibunophyllum. Sp. nov.

Plate XII., Fig. 3.

This species is separated from the preceding by the strongly-pronounced median partition, the small central area, the less numerous septa, the sparse loose vesicular tissue in the interseptal spaces, and the small fossula. Indeed, its distinctive character is so pronounced that it need not be further referred to.

It will thus be apparent that the combination of characters presented in *Dibunophyllum* is such as to place the distinctness of the genus beyond doubt; and there is also clearly indicated a series of transitions which merge from one group into other allied genera, and occupy a central position with divergent characters—showing that modification has been affected in this series by the innate tendency to variation induced in the tissues of the animal by causes of which we are ignorant. Yet that ignorance induces us more and more to admire those modifications and adaptation of parts to an ultimate whole; and thereby leads us to inquire how far, and what structural characters indicate the relationship between this group of organic remains and *Clisiophyllum.*

Genus CLISIOPHYLLUM. (Dana.)

Generic Characters. — Corallum simple, turbinate or conocylindrical, and curved. The epitheca is of variable thickness, and marked with crenulating lines and irregular annulations of growth. The calice is variable in depth, and exhibits in the centre of its floor a conical boss. The surface of the boss presents a system of lamellæ, which in some forms are more or less spirally bent; whilst in others they are straight and are attached to the inner ends of the primary septa by the intervention of a system of delicate curved plates, and extend inwards and upwards to the median styliform columella, on the crown of the conical boss, and each is united by interlamellar dissepiments. The septa are of two orders. The primary septa never extend further inwards than near to the outer margin of the central boss, and in a transverse section exhibits laminæ for a greater or less extent from their inner ends; while towards the periphery they are single, and more or less flexuous. The interlamellar space is occupied by minute

transverse granular plates ("trabeculæ"), varying in number in the different species, which in a longitudinal section are seen to pass inwards and downwards along the inner face of the laminæ. The secondary septa are of variable length; they are united by interseptal dissepiments, which are few in number near the inner ends of the primary septa, and more numerous in the external area, where they form a more or less dense vesicular tissue. The fossula is varied in size in the different varieties, but usually well marked.

The longitudinal section (Plate XIII., Fig. 5) is triareal. The middle of the central area is occupied by a median line, which extends from the inferior to the superior extremity, and presents a crest in the crown of the conical boss in the centre of the calicular cavity. On each side of the median line there is a system of vesicular tabulæ, which are directed upwards and inwards to join in the columellarian line. The intermediate area ("interlocular") space is occupied by a system of large convex vesicles; the external area ("interseptal") space is occupied by convex vesicular tissue, convexity pointing upwards and inwards, and arranged in oblique rows.

As regards the relationships of the genus *Clisiophyllum* in the general features, the external aspect presents characters of a very distinct nature, and can at all times be distinguished from all the other known genera; while, however, the central types, which are numerous,* exhibit details that clearly exemplify their generic character. There are, however, modified forms which can only be regarded as varieties, and which possess structural modifications that illustrate in the most forcible manner the alliance of the genus to other more or less related groups, and show that there are divergent characters in these modifications which indicate their transitional tendency, and which diverge in varied directions.

The genus *Clisiophyllum* is more or less related to the genera *Lonsdaleia*, *Aspidophyllum*, *Dibunophyllum*, *Rhodophyllum*, and *Cymateophyllum*. From *Lonsdaleia* (M'Coy) it is distinguished by the totally different arrangement of the septal system. In the latter they stop short and are intercepted from the periphery by a zone of vesicular tissue, which is more or less dense around the periphery, and is always compound, and gemmation is always

* For a detailed account of the different definitions and the variety of species I beg to refer to my paper in the Society's *Proceedings* for 1882. In that communication I describe twenty-one species.

produced by an enlargement of the interseptal space in which gemmation takes place, and ultimately the theca is ruptured at the lip of the calice, and is therefore lateral; and thus the young corallites grows side by side with the parent, and therefore forms compound fasciculate masses. From *Aspidophyllum* it is clearly separated. In the latter there is no median line extending from the inferior to the superior extremity of the corallum, and the centre of the corallum is occupied by more or less discontinuous vertical plates, which are united by more or less concave tabulæ, the free ends of which are seen in the centre of the calice to arise near the inner ends of the primary septa and to converge inwards, and form a helmet-shaped boss in its centre. From *Dibunophyllum* by the slightly-raised boss in the centre of the calice, which is always divided in two equal halves by a mesial partition, and by the more or less discontinuous vertical plates in the columellarian area, which are united by concave tabulæ. From *Rhodophyllum.* In the latter the boss in the centre of the calice is dome-shaped and occupied by sub-convolute lamellæ, which fold round an imaginary axis, and there is totally different structure of the central area, which is formed of discontinuous lamellar vertical plates, these being united by slightly concave tabulæ, which latter is usually of large dimensions. And from *Cymateophyllum* by the fact that the centre of the central area is more or less concave, and the lamellæ are sinuous, and frequently a portion of them extend across the centre of the columellarian area, and the sinuous discontinuous columellarian vertical plates in the central area, which are united by dense endothecal tissue.

It will thus be seen that the above marked characters of the central area are sufficiently distinct to warrant the separation of these groups in separate genera, and that while each group has central types pronounced in their structural details, in each and all of them, however, there are varieties which clearly foreshadow morphological changes which, with further development, fill up the intermediate variations, and thus merge and unite varieties into species and genera of an extremely diverse character.

Clisiophyllum bipartitum. (M'Coy.)

Plate XIII., Fig. 1.

Specific Characters.—Corallum simple, tall, cylindro-conical, and curved. The calice is deep, and exhibits in the centre of its

floor a broad conical boss. The surface of the boss is marked with a system of lamellæ, which extend inwards from near the inner ends of the primary septa, and upwards to the median columellar crest in the crown of the boss. The epitheca is moderately stout, and marked with encircling lines and irregular and shallow annulations of growth. The septa are stout, and lamellar for three-fourths of their length from their inner ends, and in the outer area they are single, thin, and flexuous. There are ten interlamellar plates ("trabeculæ") in the space of a line, which are the cut ends of the interlamellar striæ. There are sixty-two primary, alternating with an equal number of secondary septa. The latter extend inwards for nearly three-fourths of the length of the primary, and all are united by rectangular interseptal dissepiments, which are numerous in the outer area and few in number in the intermediate ("interlocular") area. The central ("columellarian") area is composed of thirty-six lamellæ, which are united to the inner ends of the primary septa by the intervention of a system of delicate plates, and a portion of them converge inwards to the median crest, whilst others stop short and become united to the larger lamellæ, and all are united by rectangular interlamellar dissepiments. The median boss exhibits the cut ends of the inner series of the interlamellar dissepiments, which, in a longitudinal section, converge inwards, and become united in the centre of the central area, and form the columellarian line that extends from the inferior to the superior extremity of the corallum. The fossula is distinct, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, four inches; diameter of calice, one inch four lines.

Formation.—Lower carboniferous.

Locality.—Found at Broadstone, Beith, Ayrshire.

Clisiophyllum oblongum. (Thomson.)

Plate XIII., Fig. 2.

This species differs from the preceding by the oblong central area, the less dense septal system, and the limited vesicular tissue in the outer area, and the smaller septal fossula.

Clisiophyllum subimbricatum. (Thomson.)

Plate XIII., Fig. 3.

This species is distinguished by the subimbricate arrangement of the central area, which indicates a transitional tendency, and is more or less related to the genus *Rhodophyllum.*

Clisiophyllum conoseptum. (Keys.)

Plate XIII., Fig. 4.

This species is readily recognized by the limited central area, the loose structural details, the irregularly arranged lamellæ, and the extension of the median crest to the fossula on the dorsal side of the corallum. The primary septa are much longer, and the sparse interseptal dissepiments, and points to a transition into the genus *Aspidophyllum.*

Clisiophyllum M'Coyianum. (Thomson.)

Plate XIII., Figs. 5 and 5A.

This species is characterised by the central area and the dense interlamellar dissepiments, which, in a longitudinal section, are exposed as closely-arranged convex cellular tissue around the columellarian rod. Its numerous septal system, and rectangular and dense interseptal dissepiments, are more to be regarded as being nearly allied to *Clis. bipartitum*, once typical of the genus. There are two groups of minute granular bodies enclosed into elongated cells, which, I believe, are ova sacs, and which I purpose referring to in detail by-and-by.

Clisiophyllum intermedium. (Thomson.)

Plate XIII., Fig. 6.

This species is so unlike all the other species of the genus, that a cursory examination of the large central area, and convergence of a portion of the lamellæ into the centre, indicates its alliance to

the genus *Centrophyllum;* while on the opposite side the lamellæ are more or less sinuous, and therefore point to a transitional tendency to *Cymateophyllum*, thus exhibiting characters that properly belong to two other groups. The central crest is the distinguishing character of *Clisiophyllum*, and therefore can only be regarded as an intermediate variety between the latter and the two former genera.

The species of this genus are not only numerous, but exhibit characters of a most diverse nature, and therefore yield a large number of varieties, which may be cursorily reviewed.

(1) *Clisiophyllum bipartitum* and *Clis. M'Coyianum* exhibit the distinctly pronounced structural details of the genus, and may thus be regarded as central types.

(2) *Clisiophyllum subimbricatum.*—While it thus possesses the median crest, and the lamellar details of the genus, yet, from the fact that a portion of the lamella being sub-convolute, indicates a transition which, with further development, would merge into the genus *Rhodophyllum.*

(3) *Clisiophyllum conoseptum.*—This species is of larger dimensions, and the structural details in the central area are of less marked clisiophylloid character; and the extension of the median crest indicates an intermediate or passage form between *Clisiophyllum* and *Aspidophyllum.*

(4) *Clisiophyllum intermedium* is distinguished by the convergence to the centre of the lamellæ on the one side of the central area; and on the other, the more or less sinuous lamellæ converging inwards point to a dimorphic transitional character, which more or less unites *Centrophyllum* and *Cymateophyllum* and the genus *Clisiophyllum.*

While there is thus indicated transitional relationships in the group, as pointed out, there are structural differences of a very marked nature, which shows clearly that the polymorphic indications are more or less universally developed throughout the series. Although I am satisfied that our investigations have not yet got beyond the threshold of the inquiry, yet, from what has been imperfectly indicated, there is no ground for doubt that the evolutionary tendency of all indicate the absorbing principle that modification is inherent, and that variation is universally identified with all organic matter.

At page 70—in which reference is made to the structural details of the genus *Zaphrentis*, and its relationships to other genera—

I referred to several of the varieties in which the septal system extends inwards to the centre of the corallum, and further stated that such varieties indicated a near relation to the genus *Densyphyllum* of Dybowskei. The generic relations of the latter I will now briefly refer to.

Genus DENSYPHYLLUM. (Dybowskei.)

Generic Characters.—Corallum simple, small, cono-cylindrical, and curved. The epitheca is stout, and marked with longitudinal ridges and annulations of growth. The calice is of varied depth in the different species, and the septa converge uninterruptedly to its centre, and at their inner ends are dense and more or less coalescent. The septa are of two orders. The primary converge inwards to the centre, and the secondary are hardly recognizable in some of the species, whilst in others they are minute. The primary septa are lamellar, and interlamellar plates ("trabeculæ") are faintly indicated. There is a septal fossula present.

In this group there is presented structural characters which may be recognized by the convergence of the primary septa inwards to the centre of the corallum; and, as formerly referred to, the relationship of the group unites it to the genus *Zaphrentis*, by the fact that in one of the species of the latter the septa converge so near the centre that it might be mistaken for a variety of the former, unless the specimen has been carefully sectioned. In *Zaphrentis*, however, a portion of the septa converge inwards, coalesce, fold round, and form the walls of the septal fossula; while in the former, the septa in no instance fold round and form the wall of the fossula; and are thus separated from the latter by the septa extending inwards to the centre of the corallum, and the totally different arrangement of the fossula. In some of the species, however, of *Densyphyllum* there are structural characters which further illustrate the transitional tendency of the group. In the normal form the septa extend into the centre of the corallum. In one variety, however, the septa more or less coalesce near their inner ends, and the central septum of the fascicula extends to the centre on one side of the corallum, while on the opposite side the septa pass into the centre, and thus indicate a modification of the normal condition, and clearly shows the mergence of a portion of the genus into another genus, to be referred

to further on, and which I propose to name the group ***Fasciculophyllum.*** In another variety of *Densyphyllum*, however, some of the septa stop short of the centre, and a spherical cell is developed at the inner ends of the short septa, and thus indicates a divergent character in another direction, and, by the possession of the cell, implies a near relationship to another group, the central area of which is occupied by a greater or less number of minute cells, and in the different varieties the cellular tissue may be traced from the variety of *Densyphyllum*, in which there is one cell exhibited, and seen to merge into a series of forms, in which the cellular tissue is more or less dense, and thus give abundant testimony to the polymorphic nature of this small and simple series of organic remains. Without further enlarging upon their generic distinctions, I will very shortly refer to a few of the specific characters, in order to illustrate their generic relationships.

Densyphyllum granulatum. (Thomson.) Sp. nov.

Plate X., Figs. 12 and 12A.

Specific Characters.—Corallum small, simple, cono-cylindrical, and curved. The epitheca is thin, and the outer ends of the septa are extended outwards through the thin epitheca, and are seen as longitudinal ridges ("costa"), which are minutely granular, and there are shallow annulations of growth. The calice is wanting. The septa are of two orders. The primary are lamellar, and extend into the centre of the corallum, and the secondary are minute, and bend laterally and become attached to the primary, and the primary septa are united by sparse interseptal dissepiments. A fossula is present, which extends into the centre of the calicular cavity on the ventral or curved side of the corallum. There are twenty-three stout primary septa, and these alternate with an equal number of minute secondary septa. I have not yet prepared a longitudinal section, but hope soon to do so, when I shall describe the structural characters as presented in the vertical section.

Height of corallum, 9 lines; diameter of section, 3½ lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Densyphyllum mammulatum. (Thomson.) Sp. nov.

Plate X., Figs. 13 and 13A.

This species differs from the preceding by the greatly stouter longitudinal ridges ("costa"), and there are mammulæ along the crown of each ridge. The septa are more numerous, the fossula does not extend to the centre, and in the centre there is one elongate cell. The septa are closely fused together, and at the inner ends are indistinct, and thus indicates by the central cell the first indication to modification.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Densyphyllum Charlestonensis. (Thomson.) Sp. nov.

Plate VI., Figs. 21, 22, and 22A.

This species is separated from the preceding by the small smooth ridges, and the epitheca is stouter. There are crenulate encircling striæ, and the large fossula extends into the centre. Two of the septa do not converge into the centre, and therefore leaves exposed a small space, which is occupied with tabulæ, and may therefore be regarded as one of the forms that unite this genus to *Zaphrentis.* I might have given a number of other illustrations, but our space will not permit.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire, where it is abundant.

Densyphyllum minutum. (Thomson.) Sp. nov.

Plate X., Fig. 5.

This delicate little species is separated from all the preceding by its minute form and the septa being more delicate, and indicates a transitional variety by the fact that a number of the septa unite into fascicles at the centre of the corallum, and on the other side several of the septa stop short, and a small portion is closed in by tabulæ, thus uniting it to the genus *Fasciculophyllum.*

Formation.—Lower carboniferous.

Locality.—Found at Nethernewton, Loudon, Ayrshire.

The relationship of this little species is so close to the genus *Zaphrentis* in the possession of the large fossula extending into the centre of the corallum, that I regarded it as belonging to the latter genus. When, however, I began to compare the more minute character of their relationships, I was induced to place it as a variety of the former, in which is exemplified the tendency to modification and variation, and in each of the species selected we have the clearest indication that, with further development, their divergent structural details clearly point to variation of microscopic proportions. While the typical species of the genus agrees in every detail with structural characters referred to by the eminent Russian palæontologist, yet in the species of the genus we have abundant evidence of their merging into *Fasciculophyllum* on the one hand, and to *Centrocellulosum* on the other. In order that the endemic conditions of the different groups may be as fully demonstrated as our space will permit, I will shortly review the genus *Fasciculophyllum*, and see whether the differentiated structure warrants us in regarding those species in which the central area is more or less fasciculate being grouped as a distinct genus.

Genus FASCICULOPHYLLUM. (Thomson.) Gen. nov.

Generic Characters.—Corallum simple, small, cono-cylindrical, and curved. The epitheca is variable in stoutness, and there are longitudinal lines, encircling striæ, and annulations of growth. The calice is of variable depth. The septa are of two orders. The primary extend inwards from the wall for a portion of their length, they then coalesce and form fasciculate groups, and usually the central septum of each fascicle extends inwards to the centre. They then unite with the elongated septum of the neighbouring fascicles and form a more or less reticulate structure in the centre of the corallum. The secondary septa are in some forms minute, while in others they extend inwards for a considerable distance, and each become united to the primary septa. The primary septa are lamellar, and there are interlamellar plates ("trabeculæ"). There is a fossula of variable dimensions.

Although differing very conspicuously in the structural details from the genus *Densyphyllum* (Dyb.), this genus is very closely allied to them, as a comparison of the figures in the accompanying plates will show, but is sufficiently distinguished by the fasciculate

characters referred to. Its relation to the genus *Centrocellulosum* is indicated by the presence of (in some of the species) indistinct cellular tissue in the centre of the corallum. In *Densyphyllum* the septa converge into the centre of the calicular cavity in typical forms. In *Densyp. minutum*, however, a few of the septa are united into fascicles in the centre on one side, while on the other they more or less extend into the centre. The genus is, therefore, distinguished by the fasciculate arrangement of the septa in typical forms, and its varieties present characters which give abundant evidence of modifications of a very marked character, varied in the passage forms, and these variations diverge in both directions; and I conceive that such modifications were induced by external causes, producing a more or less puckered or segmented arrangement in the base of the pyloric cavity of the polyp, and from the mobility and plasticity of the physiological details of the tissues in the animals, and the innate tendency to variation, and the fact that such modifications can be traced by microscopic gradations as merging and uniting structural details, which accumulate and concentrate into generic distinction.

Fasciculophyllum Dybowski. (Thomson.) Sp. nov.

Plate VI., Figs. 23 and 23A.

Specific Characters.—Corallum simple, small, cono-cylindrical, and curved. The epitheca is stout, and marked with minute longitudinal ridges, delicate encircling striæ, and shallow annulations of growth. The calice is deep. The septa are of two orders. In a corallum four lines in diameter there are twenty-two primary, which alternate with an equal number of secondary septa, and each is united by interseptal dissepiments, which are few in number and rectangular. The primary septa are lamellar, and there are interlamellar plates ("trabeculæ"). A fossula is present, and extends inwards from the wall on the ventral side of the corallum for a third of the total diameter of the corallum.

Height of corallum, 1 inch; diameter of section, 4 lines.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire, where it is abundant.

Fasciculophyllum. Sp. (?)

Plate X., Figs. 10, 10A, 11, and 11A.

This species differs from the preceding by the possession of an obovate cell in the centre of the corallum, and the inner end of the fascicles do not extend so far inwards; and the central septum extends inwards, and is united to the central cell, the fasciculate arrangement of the septa being more fully pronounced.

Fasciculophyllum. Sp. (?)

Plate VI., Fig. 27.

This species differs from all the preceding. The fasciculate arrangement of the septa are not so pronounced, and may be regarded as an intermediate variety, and to be more or less related to the genus *Densyphyllum* by the extension of a portion of the septa inwards to the centre of the corallum.

Formation.—Lower carboniferous.

Locality.—Found at Roughwood, Beith, Ayrshire.

Fasciculophyllum magnificum. (Thomson.)

Plate IV., Fig. 10.

Specific Characters.—Corallum large and simple. The septa are of two orders. The primary extend inwards to near the central area; they then coalesce, and curve laterally, and are united by the prolongation of a septum from each fascicle into a series of fasciculated groups at each extremity of the elongated central area, and a medium septum extends inwards and is united to the lateral margin of the central area on each side. The secondary septa extend inwards from the theca, and become united with the primary septa. These septa are lamellar, and there are interlamellar plates ("trabeculæ"). The central area is occupied by three lamellæ, which extend along the long axis of the central area, and are united to the fasciculate groups at each end of the long axis of the central area. The septa extend outwards through the thin epitheca, and costa are present. The fossula is problematical at the bipartite arrangement of the fasciculate septa. There

is an open interseptal space on each side of the corallum, which seems to indicate that structure. If I am correct, then there is a fossula on either side, and both extend inwards to the outer margin of the central area. There are seventy primary septa, and these alternate with an equal number of secondary septa, the extension of the latter inwards being extremely variable.

Formation.—Lower carboniferous.

Locality.—Found at Nettlehirst, Beith, Ayrshire.

Regarding the external aspect of this unique species, I can offer no description, as I have only a small portion of the corallum. The fasciculate arrangement of the septa, which coincides with the structural details of the preceding, permits of no doubt of its classificatory position. The structural details of the central area differ so much from the preceding that I regarded it as the type of another group, which I have not yet got engraved: by-and-by I hope to overtake that group. In these, however, the septa are always simple, and extend uninterruptedly inwards to the margin of the central area. In the central area, however, there are in some forms two, in others three lamellæ, extending across the long axis of the central area, and in that respect may be more or less related, but are broadly separated by the possession of the fasciculate arrangement of the septa. In the remarkable arrangement of the central area, however, there is indicated a relationship which may be yet more closely united; and I believe that other intermediate species will be discovered, the relationships of which will merge into and correlate these divergent groups. I am indebted for the portion of this corallum that I possess to Mr. Robert Dunlop, to whom I offer my cordial thanks.

Upon the whole, the genus *Fasciculophyllum*, as illustrated by the species found in Scotland, may be recognized as distinct in themselves, by the fasciculate arrangement of the septa; and while the type forms leave no doubt regarding the classificatory value, yet in the series there are divergent characters clearly indicated. In Plate VI., Fig. 27, a portion of the septa converge inwards to the centre on one side of the corallum, and on the other the fasciculate arrangement of the septa is apparent, and thus unites the latter to the genus *Densyphyllum* (Dyb.); and in *Fascic. Dybowski*, Plate VI., Fig. 23, and also in Plate X., Figs. 10 and 11, by the possession of a central and more or less spheroidal cell—thus indicating transitional structural details which clearly point

to a near relationship to the genus *Centrocellulosum;* and by the fasciculate arrangement of the septal system the genus is related to the genus *Heterophyllum.* Indeed, the series may be regarded as merging and uniting the latter, from which it is separated by the totally different aspect of the corallum. In the latter the corallites are tall cylindrical, and there are costal ridges and secondary septa in one of the species only; while in the former, the secondary septa are more or less developed in all the corallites, and the corallum is usually cono-cylindrical and small. I might have given numerous illustrations of forms in which their divergent characters may be seen united by structural details of minute proportions. We have thus clearly indicated in every stage of our inquiry a constant and persistent tendency to variation, which, when we are in possession of a more exhaustive accumulation of structural details, I venture to say that, in the coralline remains of the carboniferous system, we shall have a remarkable demonstration of modifications of a very varied nature, brought about by differentiated structural details of the most minute character. The central type of the genus clearly separate the group from allied genera; yet we have seen that there are passage forms which merge in diverse directions, and that by the possession of a central cell in some of the species there is indicated a mergence from *Fasciculophyllum* into the genus *Centrocellulosum* —a relationship which it is now my province to trace.

Genus Centrocellulosum. (Thomson.)

Generic Characters.—Corallum simple, small, cono-cylindrical, and curved. The epitheca is of variable stoutness. The calice is deep and thin around its margin. The septa converge inwards to near the centre, and in a transverse section the centre of the corallum is more or less occupied by a system of minute spheroidal cells, and the inner ends of the septa are united to the cellular tissue in the central area. The septa are of two orders. The primary extend inwards to near the centre, and these alternate with the secondary septa, which are minute and hardly recognizable, and each is united by remote and sparse interseptal dissepiments. A septal fossula is indicated.

The cellular tissue in the centre of the corallum gives considerable importance to this interesting group in thus indicating a further and persistent transitional tendency, and, while its re-

lationships have been referred to as being connected by the most minute transient structural details, it is seen that, if examined by themselves, many of the species might and would be elevated to separate and distinct genera. When, however, a large series is examined, their modified structural details are seen to be of great importance in diagnosing and grouping them with generic central types, which diverge in varied directions; and the irregularly-disposed cellular tissue in the centre of the corallum indicates a further transition, and proves that further research will demonstrate that the transitional tendency as exemplified in the structural details will merge and unite the genus *Centrocellulosum*, by relations of an intimate nature to the genus *Carcinophyllum*.

Centrocellulosum densothecum. (Thomson.) Sp. nov.

Plate X., Figs. 7 and 7A, and Fig. 9.]

Specific Characters.—Corallum simple, small, and cono-cylindrical. The epitheca is dense and thick, and there are encircling striæ and irregular annulations of growth. The calice is circular and deep. There are twenty-six septa which converge inwards to the centre. A portion of them are intercepted by spherical cells, and each is united by sparse rectangular interseptal dissepiments. The septa in this species indicates a fasciculate tendency. The secondary septa, if present, are indistinct—they may be aborted by fossilization. The fossula is small and indistinct.

Height of corallum, 1 inch; diameter of section, 5 lines.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Centrocellulosum intermedium. (Thomson.) Sp. nov.

Plate X., Figs. 6 and 6A, and Plate VI., Fig. 24.

This species differs from the preceding by the presence of a denser system of septa, and the cellular tissue is more minute. In a corallum $4\frac{1}{2}$ lines in diameter there are twenty-six primary septa, which alternate with an equal number of secondary septa. The latter are represented by minute pointed granules, and each are united by sparse interseptal dissepiments. The fossula is small.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Centrocellulosum cylindrocum. (Thomson.) Sp. nov.

Plate VI., Figs. 26 and 26A.

This species is distinguished by its slender cylindrical form, and the theca being more delicate. The diameter of the corallum is 3½ lines in the long axis, and under three lines in the narrow axis, and there are twenty-eight septa. The septal fossula is small, and the central cellular tissue is irregular in their arrangement, and indicates variation, and may be regarded as foreshadowing the sinuous, irregular structure that is exhibited in the centre of the corallum in the genus *Carcinophyllum.*

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

As regards the relationships of the genus, it will be apparent that the genus *Centrocellulosum* possesses characters which point to a group that occupy a central position, and while the typical species are distinguished by the cellular tissue in the centre of the corallum, there are structural details which clearly indicate its divergent character, and while it is closely related to the genus *Fasciculophyllum*, as indicated in some of the species by the fact that the septal system approximates to the fasciculate arrangement of the septa of that genus, it is separated from the latter by the possession of the cellular tissue in the centre of the calicular cavity, and *Centro. intermedium* has a close relation to the genus *Densyphyllum* by the fact that the septa converge too near the centre. It, however, differs from that genus in the possession of the more or less cellular tissue in the centre of the corallum, while in the typical forms of the former the septa are always united at their inner ends, and present a stellate aspect; and *Centro. cylindrocum*, by the reticulate cellular tissue in the centre, foreshadows a transitional tendency to merge into the genus *Carcinophyllum.* It will thus be evident that its polymorphic characters point to a relationship with genera whose structural details are very dissimilar from the type species of the genus, and this abundantly shows that there is no hard and fast line of demarcation even amongst genera, and that species are but modified varieties, which, with further development, would not only loose the specific distinction, but would merge into generic centres, and clearly demonstrates that genera and species are simply conventional terms, and can only be used

for convenience and aids to the palæontologist for diagnostic purposes.

As noticed in the preceding context, one of the species of the preceding genus—*i.e.*, *Cent. cylindrocum*—indicates, by the presence of the reticulate cellular tissue in the centre of the corallum, a transitional tendency to merge into the genus *Carcinophyllum* (Thomson).

Genus CARCINOPHYLLUM. (Thomson.)

Generic Characters.—Corallum simple, cylindro-conical, and cornute. The calice is variable in depth, and in some forms are averted, and exhibiting in the centre of the floor an elongated boss, which is slightly raised above the inner margin of the primary septa, which, in a transverse section, is seen to be composed of irregular reticulate cellular tissue. The septa are well developed and of two orders, and never reach the centre of the visceral cavity, and each is united by more or less numerous interseptal dissepiments.

The internal structure is triareal. The central area is occupied by irregular anastomosing vesicular tissue, which surrounds a central irregularly-formed median plate. The intermediate ("interlocular") area is composed of the inner margins of the primary septa, and united by more or less angular dissepiments. The outer ("interseptal") area is occupied by the interseptal dissepiments. The secondary septa extend inwards for a third of the length of the primary, and near the periphery they are united by acutely-angular and more or less sparsely-developed interseptal dissepiments. There is a septal fossula. The longitudinal section exhibits a series of sparse and irregular vertical plates in the central area. The intermediate ("interlocular") area is occupied by large concave plates. The outer ("interseptal") area exhibits large sparse convex interseptal dissepiments, convexity inwards.

As regards the genus *Carcinophyllum*, the reticulate cellular tissue in the central area may be regarded as a more highly developed form of the reticulate cellular tissue which characterizes one of the species of *Centrocellulosum*—*i.e.*, *Centro. cylindricum*. It, however, differs from the latter genus by the fact that the septa never extend inwards to the centre of the corallum, and, although the reticulate cellular tissue is foreshadowed in the latter yet there

are numerous intermediate forms wanting, which I have no doubt will yet be discovered, in which case the relationship will be more closely united. In one respect it resembles several of the transitionary forms of the genus *Cyclophyllum* (Plate XIV., Fig. 4), in which the structure in the central area is reticulate, but it is separated from that genus in not possessing an inner wall around the columellarian area, and the floor of the calice never presents the form of a small or inner cup. In the longitudinal section of *Carcinophyllum* the lamellar plates are sparse, and the tabulæ are remote and hardly recognizable, while in the former the structural characters are dense. The type species of the genus resembles the genus *Lonsdaleia* (M'Coy, Plate X., Fig. 2), by the fact that the septa do not reach the periphery, but are intercepted by a system of concave cells in the outer zone. It is, however, separated from that genus by the presence of a much more highly-developed septal system and the reticulate structure in the central area. In the longitudinal section of *Lonsdaleia* there is a median plate in the centre of the columellarian area, which extends from the superior to the inferior portion of the corallum. In the genus under consideration the central area is composed of irregular, sparse, and discontinuous vertical lamellar plates, and the endothecal dissepiments are hardly recognizable. It will thus be obvious that the structural details of *Carcinophyllum* are quite distinct from those of *Lonsdaleia*, the latter having a conical boss and a columellarian line in the central area, while in the former the central area is formed by loose anastomosing cellular tissue.

Carcinophyllum Kirsopi. (Thomson.)

Plate XII., Figs. 9 and 9A.

Specific Characters.—Corallum simple and cylindro-conical. The epitheca is thin and mammillated internally. The mammillations are granular, and connected to a system of elongated curved plates by delicate dissepiments. Externally there are longitudinal striæ, and there are slight annulations of growth. The calice is subcircular, everted, and moderately deep. The septa are well developed and stout. There are forty-four primary, alternating with an equal number of secondary septa, which extend inwards for a third of the length of the primary septa, and each is united by sparse and angular interseptal dissepiments. The septa are

surrounded by a system of elongated curved cellular tissue, which is connected to the epitheca by sparse and delicate dissepiments, which present around the inner margin of the everted periphery a series of elongated cells, and are divided by sparse and delicate vertical plates attached to the mammillations in the interior of the epitheca. The fossula is small, and one of the primary septa, of shorter length than the others, extends into it. The longitudinal section is triareal, and the vertical lamellæ of the central area are discontinuous and curved, and are attached to the inferior lamellæ. In the intermediate ("interlocular") area there are large concave tabulæ. The outer ("interseptal") area is occupied by sparse lenticular convex cells, convexity pointing upwards and inwards.

Height of corallum, 13 lines; diameter, 11 lines.

Formation.—Lower carboniferous.

Locality.—Found at Arbigland, Kirkcudbrightshire.

Upon the whole, it will be obvious that the genus *Carcinophyllum* is clearly separated from its nearest allies by structural details of a pronounced nature, and further illustrates that, while the relationships are more or less remote, yet in each group there are central generic types surrounded by varieties whose diverging tendencies lead into other and more modified varieties. Although there are extremely slight modifications in the structural details of many, yet we must not forget that further modifications of the same kind would and have increased the structural differences in many of these groups to a large degree, and that such differences blend into each other by an insensible series of gradations.

At page 125 I pointed out that the genus *Köninckophyllum* could be traced through the differentiated species of that genus as merging into *Histiophyllum microphyllum* (Thomson). The relationships of that genus I shall now briefly refer to, and hope to be able to show by the structural details of that genus that modification is universally exemplified throughout the entire series of these organic remains.

Genus HISTIOPHYLLUM. (Thomson.)

Generic Characters.—Corallum simple, cylindro-conical, moderately tall, and slightly curved. The epitheca is usually thin; there are annulations, and, in some forms, delicate encircling lines of growth. The calice is usually shallow, and is more or less everted, and the centre of its floor is occupied by a boss, which

is slightly raised above the inner margin of the primary septa on the dorsal or convex side, and more or less depressed or concave on the ventral side. The lamellæ pass from the inner margin of the primary septa inwards. Those of the convex side extend for two-thirds of the width of the columellarian area, where they coalesce and form a more or less irregular rod, which, in some forms, stop short of the septal fossula (Plate XII., Fig. 4), whilst in others the lamellæ converge inwards and downwards into the depression on the ventral side, and are attached to a latro-median plate, which more or less extends into the fossula on the ventral or concave side of the corallum, which in outline resembles a web (Plate XII., Fig. 6). In a corallum of an inch and a-half in diameter the columellarian area is about five lines broad.

The septa are well developed, and of two orders. The primary never extend further inwards than the outer margin of the central area, exhibiting laminæ for half their length from their inner ends, while towards the periphery they are thin, and more or less flexuous, and the secondary septa are considerably shorter, and sometimes hardly recognizable. They are united by interseptal dissepiments, which are sparse and more or less rectangular near their inner ends, but usually abundant and angular towards the periphery. There is a well marked fossula.

The longitudinal section exhibits the triareal arrangement of the internal structure. The central area is composed of thin discontinuous lamellar plates, which are united by more or less remote tabulæ, which are usually slightly convex on the dorsal and concave on the ventral side of the corallum. The intermediate ("interlocular") area is occupied by convex tabulæ—convexity upwards and inwards—which unite the inner ends of the primary septa. The outer ("interseptal") area is occupied by a zone of irregular lenticular convex cells, convexity upwards and inwards, and arranged in oblique rows.

As regards the generic relations of *Histiophyllum*, the genus forms a natural and intermediate group between the genus *Koninckophyllum* and the genus *Rhodophyllum*, and some of the species present characters in some respects that belong to the genus *Aspidophyllum*. Indeed, in some of the forms there appears to be so natural and intimate a relation to either of those genera that I long hesitated to create for their reception a distinct and separate genus; but, after carefully comparing them with hundreds of other sectioned specimens, and more especially those of its nearest allies,

I felt satisfied that the series formed a distinct and easily separable group from all existing genera. As has been formerly stated*, it is difficult to define the boundary line between each genus and its nearest allies, and in none more than in the present group; yet, after careful observation, I believe that the intermediate forms can only be classed into a natural and distinct genus.

The genus *Histiophyllum* agrees with *Koninckophyllum* in the possession of a central rod in some forms, and with *Rhodophyllum* by the fact that the lamella is more or less sub-convolute, and folds round and clasps an imaginary axis on one side of the corallum, and with *Aspidophyllum* in the possession of a large central area, the superior extremity of which projects more or less above the inner ends of the primary septa on the one side, and is usually depressed on the ventral or concave side of the corallum.

In all cases the structural details, as exhibited in the central area of the corallum, I believe are sufficient to warrant us in not only separating *Histiophyllum* from either of the above genera, but I am satisfied that it is in the structural details of the central area alone that either generic or specific distinction can be established, and I shall now point out wherein they differ from each other.

(1) The genus *Koninckophyllum* is distinguished by the possession of a compact and laterally-compressed styliform columella in the centre of its floor, which in longitudinal sections forms a thin median line, which is usually continuous from the superior to the inferior extremity of the corallum, and the space between the columella and the inner ends of the primary septa is occupied by rectangular tabulæ, which are flat in some forms, whilst in others the tabulæ are slightly raised near the columella in the central area (see Plate XI., Figs. 1A and 2A), which, as seen in a transverse section, forms a compact median rod, and is often surrounded by a few sub-convolute lines. The latter represent the cut edges of the successive tabulæ as they become elevated in the vicinity of the columella, and in some of the varieties the tabulæ are more elevated on the dorsal side of the corallum than is found on the ventral side. In these forms there is usually a series of semi-convergent plates. Such forms may be regarded as indicating the transitionary tendency of the group, thus foreshadowing the lamellar arrangement of the central area, which merge and unite the latter to the former genus, as indicated in *Hist. approximatum*

* *British Association Transactions*, 1872, p. 241.

(Plate XI., Fig. 9) and *Hist. microphyllum* (Plate XII., Figs. 7 and 8).

(2) In the genus *Rhodophyllum* the central area is formed of vertical lamellæ, which are sub-convolute, fold round an imaginary axis (Plate XIV., and Fig. 12), and present a round boss in the centre of the calice, which, in a transverse section, is seen to be united by tabulæ more or less remote. In a longitudinal section the lamellæ are discontinuous, and directed outwards and upwards, and united by concave tabulæ.

(3) In the genus *Aspidophyllum* the boss in the centre of the floor of the calice is helmet-shaped, which is round on the superior extremity on the concave side, and tapering down to the fossula, which is usually situated on the convex or dorsal side of the corallum, and there is a median lamella, which passes for two-thirds of the total diameter of the crown of the helmet-shaped boss, and downwards into the fossula, as a prominent ridge.

With these points of resemblance, there are the following differences to be noted in the forms respectively referable as allied to the genus *Histiophyllum*:—

(1) In *Köninckophyllum* there is a compressed median rod, and the space or central floor of the calice is occupied by tabulæ, which in some forms are flat, whilst in others the tabulæ are more or less raised towards the columellarian rod; while in those forms of *Histiophyllum* that are allied, the columellarian rod extends to the fossula on the ventral side of the corallum (Plate XII., Fig. 8) and the tabulæ are intersected by lamellæ which converge and coalesce with the latro-median plate on the ventral side of the corallum, and present in the floor of the calice a more or less dome-shaped aspect on the dorsal, and on the ventral side of the corallum. It is noteworthy that in all the forms I have examined the development of the lamellæ begins on the concave or ventral side of the corallum, and when the columellarian rod extends to near the fossula we frequently have the lamellæ in the first stage of development on the dorsal side of the columellarian rod—a characteristic which is always present in the passage forms in which the *Köninckophyllum* type predominates. (See Plate III., Fig. 4, in the *Proceedings* of the Society, 1879).

(2) In *Rhodophyllum* the boss in the centre of the floor of the calice is round in outline and formed by sub-convolute lamellæ (Plate XIV., Fig. 12); whilst in the allied forms of *Histiophyllum* the lamellæ are more or less sub-convolute in the dorsal,

and converge to the ventral side of the central area, where they descend and pass down into the fossula on the convex side of the corallum (Plate XII., Figs. 5 and 6).

(3) In *Aspidophyllum* the calicinal boss is prominent and helmet-shaped in outline (see Plate III., Fig. 2, in the *Proceedings* of the Society, 1879) and the median lamella passes over the boss for two-thirds of its width, and descends into the fossula in the dorsal side of the corallum, and in a longitudinal section the central lamella is single and continuous from the superior to the inferior extremity of the corallum, and the lamellæ converge towards the centre of the floor of the calice; while, on the other hand, in the allied forms of *Histiophyllum* the median lamella extends slightly beyond the centre of the central area, the lamellæ are more or less sub-convolute, and converge to and coalesce with the latro-median plate, and the boss in the centre of the calicular cavity is scarcely raised in some forms, and in others slightly raised above the inner ends of the primary septa on the dorsal, and depressed on the ventral side of the corallum, and the pseudo-columellarian rod is more or less double—a result produced by the sub-convolute lamella converging and coalescing with the latro-mesil plate that descends into the depression on the ventral side of the central area, where it passes more or less into the fossula on the convex side of the corallum.

It will thus be evident that the genus *Histiophyllum* is distinguished by the possession of distinct structural characters by which it can at all times be readily separated from its nearest allies, and that the specific relations are based upon and separable in the number and disposition of the structural details in the centre of the corallum. To some of these I will shortly refer in order to further correlate and elucidate its generic relationships.

Histiophyllum Dicki. (Thomson.)

Plate XII., Fig. 6.

Specific Characters.—Corallum simple, cylindrical and conical near the base, tall and slightly curved. The epitheca is thin, and there are irregular encircling lines and broad shallow annulations of growth. The primary septa are lamellar for fully half their length from the inner margins, and towards the periphery they

are thin and slightly flexuous. There are sixty primary, alternating with an equal number of secondary septa; the latter pass inwards from the periphery for two lines, and are attached to the primary septa at their inner ends. In the outer zone the interseptal spaces are occupied by more or less rectangular interseptal dissepiments, and in the inner ("interlocular") area they are few in number and rectangular. The central area is six lines broad, and exhibits the cut edges of the ten sub-convolute lamellæ, which converge and coalesce and form a strong latro-median rod, which passes into the fossula. The lamellæ are united by the free ends of the convex tabulæ. The fossula is small, and a single septum, three-fourths of the length of the others, pass into it.

Height of corallum, 5½ inches; diameter, 1 inch 5 lines.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Histiophyllum Ramsayi. (Thomson.)

Plate XII., Figs. 4 and 4A.

This species differs from the preceding by the greater number of septa, which are flexuous, by the more dense vesicular interseptal tissue in the peripheral zone, by the broader central area—which is more dense—and the irregular rod that extends outwards to the fossula, and the fossula is smaller and indicates a transitional tendency, and may be regarded as trimorphic.

Histiophyllum grandicum. (Thomson.)

Plate XII., Fig. 5.

This species is separated from the preceding by its larger size. The septa are not so numerous and more or less dendriform, the central area is considerably smaller, and a portion of the lamella do not reach the connecting rod, and are sub-convolute and approximate the genus *Rhodophyllum*. The connecting rod is shorter, and the fossula is smaller, and is therefore dimorphic.

Histiophyllum microphyllum. (Thomson.)

Plate XI., Figs. 7 and 8.

This elegant species is so distinct and so easily separable from all the other species, that it is almost superfluous to further refer to it. The dense and delicate interseptal dissepiments in the peripheral zone and the central area, and the fact that the lamellæ are more numerous on the one side of the central area than they are on the other and the development of the connecting rod is indicated, the fossula, being larger, indicates a relationship to the genus *Koninckophyllum*, and is therefore dimorphic.

From the above it will thus be evident that the genus *Histiophyllum*—as exemplified in the illustrations and short description of the structural details—is distinguished from its nearest allies by characters of a very marked nature; and, while the typical species clearly defines its generic distinctions, as has been shown, there are structural details which clearly point to modifications, and that these modified forms possess structural details which indicate their mergence and union to genera whose structural characters are of a diverse nature. Although they all more or less resemble each other, but in unequal degrees, the variations are in some forms extremely slight, but of the most diversified character, and abundantly illustrate that modification and reproduction have been regulated by a coefficient immutable law. Thus I am led to consider the relationships of another of these allies—*i.e.*, the genus *Aspidophyllum*.

Genus ASPIDOPHYLLUM. (Thomson.)

Generic Characters.—Corallum simple, cylindro-conical, tall, curved, and marked with circular striæ and annulations of growth. The calice is circular and shallow, and some forms are everted, whilst others are thin around the margin and moderately deep. The septa are thin, with well-marked lamina for variable distances inwards from their inner ends. These are of two orders. The primary vary in the different species; the secondary are usually short, and in some forms are hardly recognizable. The centre of the calice is occupied by a prominent boss, which is helmet-shaped, the half on the dorsal side being dome-shaped, whilst the other half slopes down to the inner margin of the primary septa on the dorsal side

of the corallum. The lamellæ are in the form of keeled ridges; the median lamella is longer than the others, and, passing over the boss, descends as a prominent keel and passes into the fossula on the ventral side of the calice. A vertical section shows that the central area is essential, and formed of laminæ which arise from the base of the corallum and is laterally united by concave interlamellar dissepiments (or tabulæ). The fossula is distinct, and usually a portion of the structural details of the central area extends into it.

For a number of years I had grave doubts as to the true classificatory value of this group, as several of the specimens, previous to their being sectioned, might readily be mistaken for and classified amongst Dana's genus *Clisiophyllum*. I have frequently seen species of this genus named *Clis. coniseptum*. Indeed, there is almost a perfect agreement in the general resemblance of the external aspect of some of the species, but a considerable difference in structural details is observed after the specimens have been sectioned. In a longitudinal section the centre of the corallum in both cases is filled up with interlamellar dissepiments that laterally unite the lamellæ, but the arrangement of each differs widely. In *Clisiophyllum* they are convex, convexity pointing upwards and outwards, and are arranged on either side of the columellarian line that extends from the inferior to the superior extremity of the corallum, and which terminates in the centre of the calice in the form of a conical boss, or like a tent, whereas in the genus *Aspidophyllum* the boss in the centre of the calice differs not only in its external aspect, being outlined like a helmet, round on the superior extremity on the dorsal side, and tapering down to the fossula on the ventral side of the corallum, but also in the arrangement of the dissepiments, which laterally unite the lamella that spring from the inferior margin of the corallum and ascend to the crown of the columellarian protuberance in the centre of the calice. These interlamellar dissepiments are always concave. The median lamella extends for two-thirds of the width of the helmet-shaped boss, passes downwards, and extends into the fossula as a prominent ridge. In all instances there is no difficulty in determining the latter where the calice is well preserved, the columellarian boss in the centre of the calice being helmet-shaped, and differing so widely in outline from *Clisiophyllum*, its nearest ally—in the latter the boss being always shaped like a tent. If, however, the perfect calice be wanting, if there is either a transverse or a

longitudinal section of the coral for comparison with the accompanying plates, the observer will at all times be enabled to identify either genera or species.

In the triareal arrangement of the structural details the genus *Aspidophyllum* is related to the genus *Dibunophyllum*. It is, however, separated from the latter by the fact that the median ridge never extends across the total diameter of the central area, while in typical species of the latter the boss is divided into two halves by the median ridge. In the forms of the latter they are more or less divergent; there is a perceptible diminution in the extension of the median ridge on the ventral side, which may be traced diminishing in extent till it merges and assumes the structural character of *Aspidophyllum*. It is therefore dimorphic, and adds another illustration to the many of the endemic tendency to variation, proving that families are indicated by their external aspect and their generic relations upon their structural details and their specific distinction upon the relative parts.

Aspidophyllum Königcki. (Thomson.)

Plate XIII., Figs. 8 and 8A.

Specific Characters.—Corallum simple, tall, cono-cylindrical, and curved. The epitheca is thin, and marked with encircling striæ and broad, deep annulations of growth. The calice is wanting, the transverse section circular. The central area is seven lines broad, and there are nine lamella, which are united by interlamellar dissepiments, and the lamellæ are attached to the inner margins of the primary septa by a system of sub-convolute plates. The lamellæ pass inwards to near the centre of the columellarian area, and unite with a system of semicircular cells, of which the lateral margin of the median plate is formed, and would present in the centre of the calice a broad ridge, tapering down to the fossula.

There are sixty primary septa exhibiting laminæ, and these alternate with an equal number of minute secondary septa, and each is united by angular interseptal dissepiments, which are dense in the peripheral zone, and few and rectangular in the interlocular area. The fossula is large, and two of the primary septa, of shorter length than the others, extend into it. The longitudinal section

is triareal; the outer area is seven lines broad, and composed of minute convex cells, convexity pointing inwards and upwards, and arranged in oblique rows. The intermediate ("interlocular") area is occupied by irregularly-disposed convex cells, convexity pointing upwards and outwards. The columellarian area exhibits a central median line and other discontinuous lines, and are united by concave tabulæ.

Corallum imperfect at both extremities, its length is 4 inches, diameter of section, $1\frac{1}{2}$ inch.

Formation.—Lower carboniferous.

Locality.—Found at Thirdpart, Beith, Ayrshire.

Aspidophyllum obovatum. (Thomson.)

Plate XIII., Fig. 7.

This species is distinguished by the less dense zone of vesicular tissue in the peripheral area, the septa less numerous, and the obovate columellarian area, in which the lamellæ are more numerous and the interlamellar dissepiments are less dense. The fossula is small. Upon the whole the structural details are not so dense as in the preceding species, and indicate a slight divergent character which can be traced in other varieties as passing into the genus *Dibunophyllum*.

Aspidophyllum Huxleyi. (Thomson.)

Plate XIII., Fig. 9.

This species is distinguished from all the other species of the genus by the broad central area and broad median plate in the centre of the calice, the short lamellæ, the limited zone of interseptal dissepiments, the large fossula, and by its tall, cylindrical form.

In this genus the structural details are pronounced, and when the calice is well preserved, the helmet-shaped boss in its centre distinguishes the genus. In the structural details of the central area, however, there is a marked difference between it and its nearest

allies, and upon the whole the type species are clearly centres, and the modified forms show clearly that variation is innate, and that differentiation and reproduction bring about relationships of a varied and diverse character.

Genus CENTROPHYLLUM. (Thomson.)

Generic Characters.—Corallum simple, cylindrical and conical near the inferior extremity, and cornute. They are tall in the cylindrical forms, while in the others they are variable. The epitheca is thin, with minute encircling lines and irregular annulations of growth. The calice is circular and moderately deep, and in some forms everted, exhibiting in the centre of its floor a slightly-elevated boss, which is formed by a series of ridges of variable number, and which are the free ends of the lamellæ of the central area, converging inwards and upwards from the inner margins of the primary septa to the centre of the calice. The septa are variable in number and stoutness, and are of two orders. The primary never extend further inwards than to the base or outer margin of the elevated boss in the central area, and exhibit laminæ for about three-fourths of their length from their inner margins, while towards the periphery they are single, thin, and more or less flexuous. The interlamellar area is occupied by minute transverse granular plates ("trabeculæ"), in number from four to twenty-two in the space of a line, which in a longitudinal section are seen to pass inwards and downwards along the inner face of the laminæ. (Plate I., Fig. 13A.) The secondary septa are minute, and hardly recognizable in the vesicular tissue that surrounds the outer zone. They are united by interseptal dissepiments, which are few in number near the inner margins of the primary septa and more or less numerous in the external area, where they form a dense vesicular tissue. The walls of the septa, the lamellæ, and interseptal tissue consists of two layers—the inner dense and granular, the outer also granular, but much less dense. The fossula is variable in size in the different varieties, but usually well marked.

The longitudinal section is triareal. The middle of the central area is composed of thin discontinuous columellarian lines, and each of these lines is united by concave tabulæ; while at the outer margin

of the central area they are convex cells, the convexity pointing upwards and inwards. The intermediate ("interlocular") area is composed of convex tabulæ, convexity upwards. These tabulæ unite the inner ends of the primary septa. The outer ("interseptal") area is occupied by more or less irregular lenticular cells, convexity pointing inwards and upwards, and arranged in oblique rows.

As regards the relationships of the genus, the general features of the external aspect present a close resemblance to those which properly belong to *Clisiophyllum*, but they are nevertheless separated by characters sufficiently distinct to warrant them being placed in a group by themselves; and, on the other hand, by the structural details of the central area there is a near relation to the genus *Cymateophyllum*. Indeed, there appears in some forms to be so natural and intimate a relation that I considered a number of the latter as varieties of *Centrophyllum*, and have thus exemplified the trimorphic character of the series.

In the three genera the outer area consists of convex vesicles arranged in oblique rows, the convexity pointing inwards and upwards, and the central area is occupied with discontinuous columellarian lines, and united by concave tabulæ in the centre of the central area; and in the lateral margins of the central area the tabulæ are convex, and the convexity pointing upwards and outwards in *Centrophyllum*, while in *Clisiophyllum* there is a median columellarian rod, and on either side there is a system of convex vesicles, convexity pointing upwards and outwards. And in *Cymateophyllum* the central area is occupied with numerous discontinuous vertical plates, which are the cut ends of the flexuous lamellæ of the central area, and each is united by concave tabulæ. And in *Clisiophyllum* there is a conical boss in the centre of the floor of the calice, formed of a system of lamellæ which converge inwards and upwards from the inner ends of the primary septa to the median axual rod in the centre. And in *Centrophyllum* the centre of the calicular cavity is occupied with a slightly dome-shaped protuberance, and formed of lamellæ, which extend inwards from the inner ends of the primary septa, and at their inner ends they unite in the centre of the boss. And in *Cymateophyllum* the central area of the calice is slightly raised above the inner ends of the primary septa, and the lamellæ extend inwards in sinuous ridges, and a portion of them extend across the total diameter of the floor of the calice. It will thus be apparent

that in each genus there are central types which are separable from the nearest allies by their structural details, which are of a diverse character, and which merge and unite their nearest allies by extremely minute gradations, and show that unless there is a somewhat complete series, would and has been the cause of considerable differences of opinion regarding the classificatory value of these organic remains. At every point of our investigation we are met with structural characters which point clearly to their relationship, but when compared with other more or less intimately connected varieties, their divergent characters leave no doubt as to their natural generic distinction, and forcibly demonstrates the endemic tendency to variation.

Centrophyllum bicentricum. (Thomson.)

Plate XIII., Fig. 10.

Specific Characters.—Corallum simple, moderately tall, conical and curved. The epitheca is thin, with crenulating striæ and broad annulations of growth. The calice is circular and moderately deep, and in the centre of its floor there is a broad and slightly elevated boss. The septa are lamellar for three-fourths of their length from their inner ends, and there are eighteen interlamellar rectangular plates ("trabeculæ") in the space of a line, which are the cut ends of the interlamellar striæ. The septa are more or less flexuous towards the periphery; there are sixty-two primary alternating with an equal number of minute secondary septa, the latter being hardly recognizable in the dense vesicular tissue that they intersect—and these are united by more or less angular interseptal dissepiments. The central area is subcircular and fully six lines broad, and in a transverse section exhibits the cut ends of the vertical lamellæ which pass inwards. Four of these converge and meet a little off the centre on the one side, and three converge and meet on the opposite side of the centre of the central area, and about one line apart, producing a bicentral aspect, and are seen in the longitudinal section to be intersected by the cut edges of the tabulæ.

The longitudinal section is triareal; in the central area there are thin discontinuous columellarian lines, and these are united by concave tabulæ. The outer ("interseptal") area is broad, and

occupied by irregular lenticular convex cells—convexity pointing upwards and inwards, and arranged in oblique rows. The fossula is moderately large, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, 3½ inches; diameter of calice, 1 inch 10 lines.

Formation.—Lower carboniferons.

Locality.—Found at Thirdpart, Beith, Ayrshire.

Centrophyllum subcentricum. (Thomson.)

Plate XIII., Fig. 11.

This species differs from the preceding by the fact that the structural details are more dense, the central area is not so broad in proportion to its breadth, and the lamellæ are more numerous, and five of the lamellæ converge and meet subcentrally on the dorsal side of the corallum.

Height of corallum, 3 inches; diameter of section, 1 inch 7 lines.

Formation.—Lower carboniferous.

Locality.—Found at Thirdpart, Beith, Ayrshire.

I might have added a more extensive series of illustrations had space permitted, in all of which the structural details are more varied than in the two illustrations that accompany this communication. I, however, selected these from the fact that their structural characters are, although different, yet nearly allied, and to illustrate the predominant character that variation in all these organic remains is almost by imperceptible gradations, and also to illustrate the divergent tendency of even the most minute structural details, induced either by external causes or the innate tendency to variation, producing modifications which, with further reproduction, merges into and unites genera whose central types leaves no doubt of their classificatory value, which, as indicated, points to the genus as an intermediate group, connected on the one side to the genus *Clisiophyllum*, and merging into and united with the genus *Cymateophyllum* on the other; which leads us through the succession of physiological modification to consider the relationships of the latter, and to inquire whether in that group there are similar transitional tendencies.

Genus CYMATEOPHYLLUM. (Thomson.)

Generic Characters.—Corallum simple, cono-cylindrical, moderately tall, and curved. The epitheca is thin, with encircling irregular ridges of growth. The calice is circular and shallow, and more or less everted, exhibiting in the centre of its floor a number of bending or wavy lamellæ, which pass from the inner margins of the primary septa to its centre, and in some forms a portion of the lamellæ pass over the central space in sinuous ridges. The septa are usually thin and of two orders. The primary never extends further inwards than the outer margin of the central space, and exhibiting laminæ for about a third of their length from the inner margin, while towards the periphery they are thin and flexuous; and the secondary septa are considerably shorter, and sometimes hardly recognizable. They are united by interseptal dissepiments, which are scanty near the inner ends of the primary septa, and abundant in the external area, where they form a dense vesicular tissue. The fossula is well marked.

The longitudinal section exhibits the triareal arrangement of the internal structure. The central area is composed of thin, discontinuous, irregular, and wavy collumellarian lines, which are united by concave tabulæ. The intermediate ("interlocular") area is occupied by convex tabulæ, which unite the inner ends of the primary septa. The outer ("interseptal") area is occupied by a zone of minute lenticular convex vesicles, convexity upwards and inwards, and arranged in oblique rows.

The genus *Cymateophyllum* is allied to the genus *Centrophyllum* in the possession of lamellæ, which in some forms converge inwards to the centre of the columellarian area; and, on the other side, its relationship to the genus *Rhodophyllum* can be traced by the fact that in some of the varieties the lamellæ on one side are somewhat sub-convolute, while on the other side they are sinuous and converge inwards to the centre of the central area. Indeed, there appears in some forms to be so natural and intimate a relation that I considered them as varieties of *Rhodophyllum*. In order that that relationship may be clearly defined, I will shortly refer to the structural character of the species selected from the group, which may be summarised in accordance to the relative value of the structural details of the central area.

[illegible]

[illegible]

[illegible]

Height [illegible] inches—imperfect. *Diameter*, 1 inch [illegible] lines.

Formation.—Lower carboniferous.

Locality.—Found in Lanehile Quarry, near Beith, Ayrshire.

Cyathaxonia Kirkeana. Thomson.

Plate XIV., Fig. 14.

In this species the septa are less numerous, the interseptal *dissepiments are* irregular and angular, the lamellæ in the central *area are* fewer in number, and on the ventral side of the corallum

they are sub-convolute, thus indicating a transition into the structural details which characterises the genus *Rhodophyllum;* and on the dorsal side the lamellæ are sinuous and arranged as is characteristic of the type species of the genus, and the interlamellar dissepiments are sparse. Thus the central area is considerably less dense in the structural details, and in the possession of the sub-convolute lamellæ on the one side; and on the other their sinuous aspect clearly points to a transitional condition, and indicates its mergence from *Cymateophyllum* into that of *Rhodophyllum* on the one side, and by the open cellular tissue in the centre, to have a near alliance to the genus *Albertia.*

Formation.—Lower carboniferous.

Locality.—Found at Thirdpark, Beith, Ayrshire.

Cymateophyllum. Sp. (?)

Plate XIV., Fig. 15.

This variety is distinguished by the fact that the lamellæ are less numerous than in any of the preceding species, and they are not so sinuous as in Fig. 16. They converge into the centre, and thus point to a near alliance with the genus *Centrophyllum;* and the central area is more circumscribed, and the septa are more or less flexuous in the outer zone, and the interseptal dissepiments are fewer in number, and irregularly rectangular.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

This species approximates so closely to some of the species of *Centrophyllum* that I had considerable doubts as to what genus it ought to be placed amongst; but after a careful examination of both genera, I felt disposed to place it as an intermediate species of the former genus, and one in which its divergent character is so nearly equally divided that at most it can only be regarded as a near variety, in which the structural details are more closely related to the former than to the latter group, and further illustrates how difficult it is to define their separate and distinct relationships. Indeed, that can only be done by the examination of an extensive and more or less connected series—more especially in the more highly-developed forms. It is noteworthy that the more complex the structural details are the variations are of a more minute character, and thus require greater attention and a more varied

series of specimens to examine before we can with any degree of certainty define either generic or specific distinctions, which indicates that we have in these transitional varieties the clearest indication that to approximately know the relationships of these organic remains the most delicate divergent structural characters must be taken into consideration. Indeed, to describe them with any degree of minuteness, I might have exhausted the entire available space with the details of the near allies of the genus. In those referred to, however, there is abundant testimony to the fact that all are liable to modification, and in these, as in all of the preceding genera, the structural characters diverge in all directions.

The near relation and transitional tendency in *Cymat. Harknessi* to merge into and to unite in the divergent species of the genus *Rhodophyllum* on the one hand, and to the genus *Albertia* on the other, implies our consideration of the development of the latter genus.

Genus Albertia. (Thomson.)

Generic Characters.—Corallum simple, cylindro-conical, curved, and tall. The epitheca is thin, with minute, crenulate, encircling lines and irregular annulations of growth. The calice is circular and shallow, and in some forms everted, exhibiting in the centre of its floor a series of irregular ridges, which more or less converge inwards and downwards from the inner margins of the primary septa to near the centre of the calice. There is a depressed space in the centre, formed by concave tabulæ, which in a transverse section are seen to form the walls of the central depression, concavity outwards and downwards. The septa are thin, and of two orders. The primary never extend further inwards than to the outer margin of the central area, and exhibit laminæ for about half their length from the inner margin, while towards the periphery they are thin and flexuous, and there are interlamellar plates ("trabeculæ"). The secondary septa are minute, and hardly recognizable. They are united by interseptal dissepiments, which are sparse near the inner boundary of the primary septa, and abundant in the external area, where they form a dense vesicular tissue. The fossula is usually small, but well marked. The longitudinal section is triareal, the central area is composed of thin discontinuous columellarian lines, and each is united by concave tabulæ. The intermediate ("interlocular") area is composed of

convex tabulæ, convexity upwards, which unite the inner ends of the primary septa. The outer ("interseptal") area is occupied by a zone of more or less irregular lenticular convex cells, convexity upwards and inwards, and arranged in oblique rows.

The genus *Albertia* was established by myself* for the reception of a large group of corals, presenting a combination of characters distinctly different from any of the existing genera. It may, however, be regarded as in some respects intermediate between the genus *Aspidophyllum* and the genus *Cymateophyllum*, and as exhibiting structural characters which closely link it to the genus *Aulophyllum*. As regards its structural details, it may be distinguished by characters of a distinct nature.

Firstly, The corallum in *Albertia*, like that of *Aspidophyllum* and *Cymateophyllum*, is triareal in composition. Indeed, there is a striking similarity in the external and intermediate areas in the three groups. The chief characters which distinguish *Albertia* are the form and arrangement of the lamellæ or ridges in the central area, which are slightly raised above the inner margin of the primary septa, and in outline are more or less round, and formed by convex plates—the convexities being parallel to the planes of the ridges. The ridges converge inwards and downwards, but stop short of the centre, and are attached to the outer margin of the depression, a shallow cup in the centre of the floor of the calice. The walls of the central depression are formed of concave tabulæ, which converge inwards and downwards, the centre of which, in a longitudinal section, is seen to consist of minute transverse tabulæ. The structural details of the central area of the corallum are, I believe, sufficient to warrant us in separating *Albertia* from the genus *Aspidophyllum*. In the latter the boss in the centre of the calice is helmet-shaped in outline, and dome-shaped on the ventral or concave side of the corallum, and slopes down on the dorsal or convex side to the inner margin of the primary septa. The free edges of the vertical lamellæ of the central area appear on the crown of the boss as so many keeled ridges, and the median ridge passes over the boss and descends into the fossula on the dorsal side of the corallum, forming a more or less continuous median line.

Secondly, The genus *Albertia* agrees with *Cymateophyllum* in the triareal arrangement of the structure, and, as before stated,

* Philosophical Society *Proceedings* for 1878.

I believe that it is in the central area alone where true generic distinction exists. The only point which I deem it necessary to notice is the central area, which in *Cymateophyllum* is slightly raised above the inner margin of the primary septa and is formed of vertical lamellæ, the superior extremity of which appears as wavy ridges, and which pass from the margin of the primary septa to the centre of the floor of the calice, the cut edges of the vertical lamellæ appearing in transverse sections as so many waving or bending lines, which pass from the inner margin of the central area to its centre. On the other hand, in *Albertia* the ridges that are exposed in the central area fall short of the centre or floor of the calice, and the centre of the shallow cup or depression is closed in with minute tabulæ—a feature which also characterises the genus *Aulophyllum*.

Thirdly, There falls now to be considered the genus *Aulophyllum*, in respect of which the only point which calls for special remark is the depression in the centre of the calice. In the genus *Aulophyllum* the centre of the corallum is cup-shaped, and the periphery is formed of minute and closely-arranged lamellæ, which pass sharply downwards, and are attached to the tabulæ, which forms the floor of the central area. The superior extremity of the corallum presents in outline the form of a double cup, a very marked distinction. As in *Albertia*, the calices are shallow and more or less everted, and the superior extremities of the vertical lamellæ are conspicuous, round in outline, and irregular in arrangement.

Albertia intermedium. (Thomson.)

Plate XIV., Fig. 13.

Specific Characters.—Corallum simple, cylindro-conical, tall, and curved. The epitheca is thin, and there are delicate encircling lines, and broad irregular annulations of growth. The calice is wanting. The transverse section is circular. The primary septa are lamellar for nearly two-thirds of their length from the inner margin, and in the outer area they are thin and more or less flexuous. There are seventy-two primary septa, alternating with an equal number of secondary septa. The latter pass inwards from the periphery for a line and a half, and are attached to the primary septa at their inner ends. In the outer zone the interseptal spaces are occupied by scarce and moderately angular dissepiments, while in the centre they become numerous, and in the

inner ("interlocular") area they are few in number and rectangular. The central area is seven lines broad, and exhibits the cut edges of nine lamellæ, which never reach the centre, and occupy two-thirds of the central area. The septal fossula is narrow, and a single primary septum, three-fourths of the length of the others, passes into it.

The longitudinal section is triareal, and the vertical lamellæ are seen to stop short of the centre of the corallum. The centre is occupied with concave tabulæ. In the intermediate ("interlocular") area there are convex tabulæ, the convexity being upwards and outwards. The outer ("interseptal") area is broad, and exhibits numerous irregular lenticular convex cellular tissue, the convexity being upwards and inwards, and arranged in oblique rows.

Height of corallum, $4\frac{1}{2}$ inches; diameter of transverse section, 1 inch and 10 lines.

Formation.—Lower carboniferous.

Locality.—Found in Langside, Beith, Ayrshire.

In consequence of having unduly encroached upon the available space, and the large variety of illustrations that accompanies this communication, I am unable to do more than refer to my paper on the genus *Albertia*, published in the Society's *Proceedings* in 1879. In that communication I have described seven species of this genus, and each of the species is distinguished by the variously arranged septa, or dissimilarity of the structural details of the central area. In several of these species the variation of the structural details is apparently slight. When, however, each species is examined and compared with its nearest allies, we find that the modification is sufficiently distinct to warrant them being placed as distinct separate forms. Indeed, in this as in all the more highly-developed groups, variation is so minute that it requires the closest attention to define their specific distinction. In all, however, their variable characters are pronounced, and if differentiation is expressed in microscopic proportions, such simply exemplifies that in the more highly differentiated forms modification must of necessity become more and more minute in details. That they do differentiate, minute though the differences be, induces us more and more to realise that there is in all an endemic tendency to variation, which, with further modification, induces greater complexity in the structural characters of the series.

With regard to the relationship of the genus *Albertia*, a careful comparison of the structural details leaves no doubt that its classificatory position is clearly defined, and that while there are structural characters which more or less indicate a near relation to allied genera, and through its modified details we can trace its mergence into the genus *Aspidophyllum* on the one hand, and on the other it is related to the genus *Cymateophyllum* in the possession of flexuous lamellæ on the one side of the corallum, and by the possession of a more or less depressed central area, and the occupation of the central area by concave tabulæ, thus presenting the aspect of a shallow cup, which, when more fully developed, is the structural character of the genus *Aulophyllum*—thus not only indicating generic modification of a diverse nature, but also foreshadowing a transitional tendency to merge and to unite family relationships which, with further development, the central cup becomes deeper and deeper, until in outline it is deeply concave; and with further development it assumes the form of a double cup, which is the distinguishing character of the family *Diplocyathophyllidæ*. Illustrations of such modifications could be given if space would permit.

As stated when referring to the generic relationships of the genus *Cymateophyllum*, we found that in one of my illustrations I referred to its alliance with the genus *Rhodophyllum*, which induces me now to refer to the structural details of that genus, and to inquire into its relationships.

Genus Rhodophyllum. (Thomson.)

Generic Characters. — Corallum simple, usually tall, conocylindrical, and curved. The epitheca is thin, and there are encircling striæ and annulations of growth. The calice is circular and shallow, its edges are more or less everted, and exhibiting in the centre of its floor a dome-shaped or rounded boss, which is but slightly raised above the inner margin of the primary septa. The surface of the boss is marked by a number of spirally-twisted ridges which proceed from its margin to its summit, where there is no distinct median crest or keel. The septa are of two orders, the primary never extending further inwards than the outer margin of the central boss, and the secondary septa are considerably shorter and sometimes hardly recognizable. The internal structure is triareal. The central space ("interlamellar")

area is formed by the intersection of a series of irregular and vesicular tabulæ. As seen in transverse sections, the intersection of these two series of plates give rise to a number of lines which, though irregular, are in the main folded in a spiral or contorted manner round an imaginary centre. The central area is not partially or wholly divided into two parts by any predominant lamella, nor are the vertical lamellæ regularly arranged in a radiating manner from the circumference of the central area towards its centre. The intermediate ("interlocular") area is composed of nearly horizontal loosely anastomosing tabulæ, and the inner lamellar ends of the primary septa extend into it. The outer ("interseptal") area is occupied by the septa, which, in this portion of the corallum, are delicate and more or less flexuous, and are united together by very numerous, close-set, anastomosing dissepiments. There is thus produced an exterior zone of dense vesicular tissue, the vesicles of which are arranged in oblique rows directed upwards and inwards. The longitudinal sections show that the central area is intersected by several discontinuous, and often wavy, columellarian lines, and the transverse section exhibits a well-marked septal fossula.

The genus *Rhodophyllum* is more or less related to the genera *Clisiophyllum*, *Centrophyllum*, *Cymateophyllum*, and *Albertia* in the possession of a large central area, the superior extremities of which projects above the floor of the calice as a central eminence or boss, which is formed by vertical lamellæ, the free ends of which appear as so many bending or wavy ridges on the surface of the boss, and the cut edges of the vertical lamellæ appear in a transverse section as variously arranged converging lines which converge from the margin of the central area inwards to its centre, and each is laterally united by a series of interlamellar dissepiments.

It is in the structural details of the central area of the corallum that *Rhodophyllum* exhibits its distinctive character, and these are sufficient to separate the genus from its nearest allies. The structural details are as follows:—In *Rhodophyllum* the calicinal boss is rounded and of no great height, and there is no median crest. Its surface is marked with spirally-twisted ridges which ascends from its margin to its summit, and folds round and clasps an imaginary axis. In the longitudinal section the tabulæ are intersected by discontinuous and irregularly disposed vertical

columellarian lines, and laterally united by concave tabula. While in the genus *Clisiophyllum* the boss in the centre of the calice is prominent and conical, and in some species there is a system of ridges which extends directly inwards and upwards, and in other species they are more or less spirally-twisted, and all extend from the margin inwards and upwards, and in other species they are more or less spirally twisted, and all extend from the margin inwards and upwards to the median crest on the crown of the conical protuberance, which in a longitudinal section is seen to extend from the inferior to the superior extremity of the corallum as a median columellarian line. It is therefore in the spirally-twisted lamellæ in those forms in which a transitionary tendency is indicated that we find a remote relationship to the genus; but the latter is broadly separated from the former by the prominent conical boss, the median crest, and the central columellarian line, structural details that are never present in the former. And *Centrophyllum* is separated by the fact that the lamellæ converge and unite in the centre, and the boss is slightly raised, but never presents the rounded form, nor do the lamellæ ever assume a twisted aspect. And *Cymateophyllum* is readily recognized by the slightly raised central eminence, which is more or less depressed in the centre, and the lamellæ are always wavy or sinuous, and some of them extend across the central area; and it is only in one of the varieties that we find on one side of the central area a disposition to become slightly twisted—thus indicating a tendency to divergence. And *Albertia* is separated by the totally different aspect of the central area, which is slightly raised above the inner ends of the primary septa, and by the central concavity, and the centre of the floor is occupied with tabulæ, which in a longitudinal section is concave and laterally unites the discontinuous columellarian lines. In a transverse section there is more or less exposed a small central open space in both genera, which is the superior face of the convex tabulæ; and in this respect the latter resembles the former genus, but is clearly distinct by the short lamellæ, which never reach to the centre of the central area and are never twisted, as in the former.

Rhodophyllum Phillipsi. (Thomson.)

Plate XIV., Fig. 12.

Specific Characters.—Corallum turbinate, short, and marked with

minute encircling lines and irregular annulations of growth. The calice is circular and moderately deep, the columellarian boss rotund, and slightly raised above the inner margin of the primary septa, and formed by sub-convolute lamellæ, which are united by interlamellar dissepiments. The septa are numerous. There are sixty primary exhibiting well marked laminæ near their inner margins. Where they are fusiform, and curved gently towards the fossula, or from left to right, there is interlamellar plates ("trabeculæ.") There is an equal number of secondary septa, which pass inwards from the wall for about two lines, there they bend and become united to the primary septa, and each is laterally united with numerous angular dissepiments, which fill up the interseptal spaces. The fossula is large, and three of the primary septa of shorter length than the others extend into it.

Height of corallum, 2 inches; diameter of calice, 1 inch and 11 lines.

Formation.—Lower carboniferous.

Locality.—Found at Langside, Beith, Ayrshire.

I dedicated this species* to the late Prof. John Phillips, F.R.S., as an expression of my appreciation of his uniform urbanity and kindness, nowhere better exemplified than in Section C, at the Meetings of the British Association.

I possess a large and varied series of this genus; and in order that the divergent character may be realized I will shortly refer to those forms that have been described.

(1) *Rhodophyllum Craigi* (Thomson). This species is distinguished from the preceding by the possession of a broader central area. The septa are more numerous, there being eighty-eight primary and an equal number of secondary septa, and the interseptal dissepiments are considerably more numerous and the fossula is smaller.

Formation.—Lower carboniferous.

Locality.—Found at Langside, Beith, Ayrshire.

(2) *Rhodophyllum simplex.* This species differs in the structural details of the central area, the lamellæ are more convolute, and there are fewer interlamellar dissepiments, and it is altogether considerably more simple in its structural characters.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

* Geological Magazine, Decade II., Vol. I., 1874.

(3) *Rhodophyllum Romeri* (Thomson). This species is characterised by the broad central area. The lamellæ are not so numerous. The septa are more delicate, and in greater numbers. There are seventy-four primary, and these alternate with an equal number of secondary septa. The interseptal dissepiments are more dense, and the fossula is smaller, and on the whole it may be regarded as intermediate in all its details between *Rhod. Phillipsi* and *Rhod. Craigi*.

Formation.—Lower carboniferous.

Locality.—Found at Langside, Beith, Ayrshire.

(4) *Rhodophyllum reticulatum* (Thomson) is separated from all the previous forms by the fact that the septa are not so numerous, and the dense reticulate structure of the central area; and in this respect is related to several species of *Clisiophyllum* (Dana), but is separated from that genus by the non-possession of a columellarian rod.

Formation.—Lower carboniferous.

Locality.—Found at Langside, Beith, Ayrshire.

(5) *Rhodophyllum Slimoni* (Thomson). In this species there is a marked difference by its large form, it being not less than half-an-inch broader than any of the other species. The septa are stout and vesicular in their inner half, and dendriform and delicate in the outer peripheral zone. There are only forty-four primary, and these alternate with an equal number of secondary septa, and structural details of the central area is less reticulate than the latter — but more so than in any of the former species; and three of the lamellæ meet near the centre of the central area, and thus indicates a remote relationship to the genus *Centrophyllum*.

Upon the whole, while this genus is distinguished by characters of an unusually marked kind, yet in the less pronounced varieties we find an intimate relation to *Clisiophyllum* on the one hand, and to *Centrophyllum* in the other; and when all the varieties are engraved and properly illustrated, this genus will abundantly exemplify its polymorphic nature, and clearly illustrate the endemic tendency to variation, and will show that in each modification, with further development, its divergent structural details merges and unites its generic relationships in all directions.

In all the preceding forms I have tried to show that the tendency to variation is apparent in every group, and that the generic relationships are polymorphic, and may be traced merging from

one species into other allied forms; but, from the innate tendency to variation, we have found how difficult it is to draw the line of demarcation between even genera. We have also found that in several genera there is indicated a further modification, and that, by the depression of the central area, and it becoming more and more depressed, there is thus foreshadowed a divergent character sufficiently pronounced to warrant us in regarding such modifications as indicating a mergence into another group, which I have ventured to show as belonging to a distinct and separate family, and have, by the structural aspect of the central area, been induced to designate under the family name of *Diplocyathophyllidæ*.

FAMILY DIPLOCYATHOPHYLLIDÆ.

(Thomson.) Fam. nov.

Corallum simple, septa well developed, and extending inwards about a third of the total diameter of the corallum. Septal fossula variable, columella tubular. The longitudinal section presents the form of a double cup at the superior extremity (Plate XIV., Figs. 3 and 8).

The form and structure of this family are so distinct, and differ so widely from all the other groups of coralline remains that have hitherto been discovered in the carboniferous rocks, that the double cup and the septal system around the inner margin of the cup suggests that it is probable these septa are the expression of a double circlet of tentacles—an outer around the periphery of the corallum and an inner around the periphery of the tubular columella. Deeming such probable, I have reconstructed a model of the aspect I conceive the polyp presented when in life, the upper portion representing the polyp's body, while the lower, or the portion below the circular line, represents the sclerodermic corallum (Plate I., Fig. 2).

Genus AULOPHYLLUM. (Edwards and Haime.)

Generic Characters.— Corallum simple, variable in height, conical, cylindro-conical, and curved. The epitheca is thin, with fine encircling lines and annulations of growth. The calice is deep. In some forms it is thin around the periphery, in others they are

more or less everted, exhibiting in the centre of its floor a cup-shaped projection (Plate XIV., Fig. 8). Its wall is formed by a system of curved plates which arise at the inner ends of the primary septa, bend downwards, fold round the cylindrical columella, and form its mural investment. The septa are of two orders. The primary extend inwards, but always stop short of the wall of the cylindrical columella, and exhibit laminæ for about four-fifths of their length from their inner margins, while near the periphery they are thin and single. The interlamellar area is occupied by minute transverse granular plates of variable number in the space of a line, which, in a longitudinal section, are seen to pass downwards and inwards along the inner face of the laminæ (Plate XIV., Fig. 8A). The secondary septa in some forms extend inwards about half the length of the primary septa, whilst in others they are minute and hardly recognizable in the vesicular tissue that surrounds the outer zone. They are united by interseptal dissepiments, which are few in number near the inner margins of the primary septa, and more or less numerous in the external area, where they form a dense vesicular tissue.

The walls of the septa and the interseptal tissue consists of two layers—the inner dense and granular, the outer also granular, but much less dense.

The fossula is variable in size in the different forms, but usually well marked. The longitudinal section—Plate XIV., Fig. 8, is triareal. The central area is occupied by a cylindrical columella; its wall is formed of curved plates, which extend from the inner ends of the primary septa, and at their inner ends they curve inwards and unite with a system of plates that bend and pass downwards, and rest upon the minute tabulæ that occupies the centre of the visceral chamber, and which divide the central space into minute transverse cells.

The intermediate ("interlocular") area is occupied by convex tabulæ, convexity pointing upwards and slightly outwards, and unite the inner ends of the primary septa.

The outer ("interseptal") area is occupied by more or less irregular lenticular convex cells, convexity pointing upwards and inwards, and arranged in oblique rows.

The genus *Aulophyllum* of Edwards and Haime present a combination of characters distinctly different from all the other existing genera. In the general features of the external aspect the forms present a close resemblance to those which properly belong to the

genus *Cyclophyllum*, but they are, nevertheless, separated by characters sufficiently distinct to warrant their being placed in a group by themselves. It may, however, be regarded as in some respects intermediate between the genus *Cyclophyllum* and the genus *Albertia*. As regards its relationships it may be distinguished by characters of a fundamental nature.

Firstly, The corallum in *Aulophyllum*, like that of *Cyclophyllum* —the next genus to be referred to—and *Albertia*, is triareal in composition. The chief characters which distinguish *Aulophyllum* are the cylindrical columella, and the periphery is formed of minute and closely-arranged plates, which pass upwards, curve at their inner ends, and are attached to a series which pass sharply downwards, and rest upon the minute tabulæ, which form the floor of the central tubular columella, which in a longitudinal section, if made down the axis of the corallum, presents the form of a double cup, and the bottom of the cup is closed by minute flat tabulæ.

Secondly, The genus *Aulophyllum* agrees with the genus *Cyclophyllum* in the triareal arrangement of the structure, and in the fact that each possess a tubular columella; and, as I have long been convinced that it is in the central area alone where true generic distinction exists, the only point which I consider it necessary to notice is the centre of the columellarian area, where in both genera the periphery is exposed projecting above the inner ends of the primary septa. In *Cyclophyllum*, however, in a longitudinal section, if made along the axis of the corallum, it also presents the form of a double cup. The centre of the columella, unlike the tabulæ in *Aulophyllum*, is occupied by more or less discontinuous lamellæ, and these are united by minute vesicular tissue.

Thirdly, There falls now to be considered the genus *Albertia*, in respect of which the only point which calls for special remark is the arrangement of the central area. In the genus *Albertia* like that of the genus *Aulophyllum*, there is a depression in the centre of the columellarian area; it, however, never assumes the cup-shaped aspect of the latter, and there is no cylindrical tube, and the central area is occupied by a system of lamellæ, which extend inwards from the inner margin of the primary septa, and stop short of the centre, and are attached to the outer margin of the depression or shallow cup in the centre of the floor of the calice. The walls of the central depression are formed of concave tabulæ, which converge inwards and downwards, the centre of

which, in a longitudinal section, is seen to consist of minute transverse tabulæ (Pl. XIV., Fig. 8). The chief features that distinguish the genus *Aulophyllum* is the superior extremity of the corallum, presenting in outline the form of a double cup. In the genus *Albertia*, the calices are shallow and more or less everted, and the superior extremities of the vertical lamellæ are conspicuous, round in outline, and irregular in arrangement—a very marked distinction.

It will thus be seen that the above marked characters of the central area are sufficiently distinct to warrant the establishment of the group into a distinct genus, as the more I investigate the corals of the carboniferous rocks, the more I am persuaded that it is only in the structure of the central area that there is any classificatory value for either generic or specific distinction.

Aulophyllum Wünschi. (Thomson.)

Plate XIV., Fig. 6.

Specific Characters.—Corallum simple, short, turbinate, and much curved near its base. The calice is shallow, its margin is thin, and the central area is shallow and slightly raised above the inner ends of the primary septa. The epitheca is thin, and the outer ends of the primary septa are exposed as longitudinal ridges through the thin epitheca. The septa are of two orders. There are fifty-six primary, alternating with an equal number of secondary septa. The latter extend inwards from the periphery for half the length of the primary septa, and all are united by rectangular interseptal dissepiments, which are numerous in the outer zone and sparse in the intermediate ("interlocular") area. The primary septa are lamellar for five-sixths of their length from their inner ends; in the outer peripheral zone they are single. There are ten interlamellar plates in the space of a line, which are the cut ends of the interlamellar striæ. The central area, as exposed in the transverse section, is ovate, and accuminate opposite the fossula. Its wall is composed of irregular lenticular convex plates, convexity pointing outwards, and united to the inner ends of the primary septa by the intervention of a system of angular plates; and around the inner margin of its periphery there is a cyclum of irregular and sparse septa. Some of these are more or less sinuous, and converge inwards to near the centre of the central area, and

all are united by endothecal tissue of varied aspect and density. The fossula is small, and a septum, of half the length of the others, extends into it.

Height of corallum, 2 inches; diameter of section, 1 inch.

Formation.—Lower carboniferous.

Locality.—Found imbedded in the brecciated conglomerate that is interstratified between the red sandstone at the Cock of Arran—regarding the age of which several of the authors that have described the sections of the northern end of Arran are not agreed. Some regard the sandstone and conglomerate of the northern point, or Cock of Arran, as of old red sandstone age, while others have regarded it as of Permian age. The discovery of this coral, and a considerable number of other well-authenticated carboniferous fossils, establish beyond doubt that these rocks were deposited posterior to the deposition of the marine series of the carboniferous system. My own conviction is, that they are the equivalents of the millstone grit. Rocks of a similar colour and composition—and their superposition to the inferior marine series has a striking identity—are well exposed along the coast line to the south of Dunbar, Haddingtonshire. I have found this same species in the shale that overlies the lowest bed of limestone in Corrie Mines, Arran.

Aulophyllum fungites. (Edwards and Haime.)

Plate XIV., Fig. 8.

A longitudinal section, to show the double cup, the tabulæ in the central area, and the deep calicular cavity. The spaces where the structure is wanting in the interlocular area, on each side of the calice, is filled in with impure sedimentary matter, and hence obscures the structural characters.

Aulophyllum Haimei. (Thomson.)

Plate XIV., Fig. 9.

This species is distinguished from the preceding by the less dense structural details in the central area and the less exposed tabulate

space in the centre of the central area. The septa are more delicate, the zone of vesicular tissue in the peripheral zone is considerably denser, and the fossula is smaller.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Aulophyllum expansum. (Thomson.)

Plate XIV., Fig. 7.

This species is separated from the former by the smaller central area, which is accuminate opposite the fossula. The septal system in the central area is more dense, and several of the septa extend inwards towards the centre, and thus indicating a tendency to modification, which can be shown in other species to assume a loose cellular aspect, and to merge into the genus *Cyclophyllum* (Duncan and Thomson). The zone between the inner ends of the primary septa is broader, and the cellular tissue less dense.

Formation.—Lower carboniferous.

Locality.—Found at Charleston, Fifeshire.

Aulophyllum Patricki. (Thomson.)

Plate XIV., Fig. 11.

This gigantic species is distinguished from all the other species of the genus by characters of a very marked kind. Indeed, the structural difference is so pronounced that it is almost unnecessary to do more than simply refer to the illustration that accompanies this communication. It will be apparent that the arrangement of the lamellæ clearly points to its transitional tendency, and may be regarded as indicating its mergence into the genus *Albertia.* It is allied to *Albertia* by the possession of a system of lamellæ in the central area. It, however, differs from *Albertia* by the fact that the lamellæ do not intersect the tabulæ, while in *Albertia* the lamella extends from the superior to the inferior part of the corallum, and the tabulæ never extend across the central area, but are more or less intersected by the vertical lamellæ, and the centre of the central area is more or less closed in by a series of down-curved plates, and exposes loose vesicular tissue in the centre of the visceral chamber; while in *Aulophyllum* the tabulæ is seen to

extend more or less across the centre of the visceral chamber in the longitudinal section, and in a transverse section the superior face of the tabulæ is always exposed in the centre of the central area, and therefore possess characters which unite it to the genus *Aulophyllum.*

Height of corallum, imperfect—the portion I have is 6 inches long; diameter of section, 2 inches and 3 lines.

Formation.—Carboniferous.

Locality.—Found in the bed of shale that overlies the lowest bed of limestone in Langside Quarry, near Beith, Ayrshire.

It will thus be apparent that while the genus *Aulophyllum* is distinguished from all the other genera by characters of a fundamental nature, and can at all times be recognized by the double cup, by the open space in the central area, or the free face of uppermost tabula, and the deep groove between the inner ends of the primary septa and the tubular columella, yet in it, as in all the other genera, there is no finality in the arrangement of the structural details of the central area. A few of these divergent characters may be briefly summarised as follows:—

(1) In *Aulop. Wünschi* the tabulate centre of the central area is freely exposed, the central area is broad, and its septal system numerous.

(2) In *Aulop. expansum* the central area is much smaller, the groove around its margin is broader, the septa of the inner zone are much more minute and numerous, and several of the septa extend inwards and impinge upon the face of the tabulæ, and expose a more or less loose reticulate aspect.

(3) In *Aulop. Haimei* the structural details in the central area are less dense, and more or less reticulate, and the centre is greatly circumscribed by the extension inwards of the inner zone of septa, and thus merges so near to the genus *Cyclophyllum* that it becomes difficult to define their generic distinction.

(4) In *Aulop. Patricki.* In this species the tabulæ of the central area are broad. There is, however, a marked difference of the septal system in the columellarian area. Indeed, their union with the inner ends of the primary septa, their lamellar aspect, and the arrangement of the septa in the columellarian area, which merges so closely upon the lamella of other groups, all clearly point to its relationship with the genus *Albertia.*

It will thus be apparent that while the central space is sufficiently pronounced in the central types, and leaves no doubt as to their

generic distinction, yet, there are divergent species with mergent forms, which become united to allied genera on both sides, and thus exhibits their variable tendencies; and I believe that if other forms were sectioned, the separation of the seeming divergent genera would be obsolete, and would thus add another series of demonstrations to show that variation in the tissues of the living animals has been microscopic in detail, and that each minute deviation from the central type of each group demonstrates to the universality of the endemic tendency to variation, and that each modified form becomes a centre around which other modifications arise, and amply demonstrates the consanguinity of these organic remains.

From what has been stated it will be apparent that the next group that falls to be referred to, and whose relationship has been indicated, are grouped under the genus *Cyclophyllum* (Duncan and Thomson).

Genus Cyclophyllum. (Duncan and Thomson.)

Generic Characters.—Corallum simple, cylindro-conical, cornute, and curved. The cylindrical forms are frequently curved and twisted, while the cornute forms are stouter and never so tall. The epitheca is variable in stoutness. The calice is usually deep. Those forms with the deep calices are thin around the margin, while those varieties whose calices are not quite so deep are not so thin, and in some it is more or less everted, exhibiting in the centre of its floor a cup-shaped projection, which is more or less raised above the inner margin of the primary septa (Pl. XIV., Fig. 3), which in a transverse section is seen to be surrounded by a system of minute septa, which converge inwards, coalesce, and assume a more or less reticulate aspect in the centre of its floor (Pl. XIV., Fig. 1). The septa are variable in number and stoutness, and are of two orders. The primary septa never extend into the wall of the cylindrical columella, but are united to the central mass by a system of sub-convolute plates, which fold round and form the wall of the columella. The primary septa exhibits laminæ to near the periphery. Near their outer margins they are single and thin. The interlamellar spaces are occupied by minute transverse granular plates, in number from six to sixteen in the space of a line, which, in a longitudinal section, are seen to pass

inwards and downwards along the inner face of the laminæ (Pl. XIV., Fig. 3A). The secondary septa usually extend inwards for fully the half-length of the primary. They are united by interseptal dissepiments, which are few in number near the inner margins of the primary septa, and more or less numerous in the external area. The walls of the septa, the interseptal tissue, and the endothecal structure consist of two layers—the inner dense and granular, the outer also granular, but much less dense. The fossula is variable in size in the different varieties, but usually well marked.

The longitudinal section (Pl. XIV., Fig. 3) is triareal. The central area is tubular, and composed of thin discontinuous vertical columellarian laminæ, and each of these laminæ is united by concave tabulæ, while the outer margin is composed of convex cellular tissue, convexity pointing outwards and upwards, and forming the wall of the tubular columella. The intermediate ("interlocular") area is occupied by convex tabulæ, convexity upwards, and unite the inner ends of the primary septa. The outer ("interseptal") area is occupied by more or less convex cellular tissue, convexity upwards and inwards, and arranged in oblique rows.

This genus has been known to me for upwards of twenty-four years. They form so natural and so well-marked a group that their identification can at all times be easily recognized, even with the most cursory knowledge of the corals of the carboniferous system; but I have delayed publishing the results of my own observations until I had procured all the evidence that my time would admit of. Before, however, I finally decided to place the results of my investigations on record, I went to Paris and examined the type specimens of M. Edwards and J. Haime, and also examined the specimens referred to by these authors that are in the Museums of London and Bristol; also the collection in the Dublin Museum, and all the private collections that I had access to; and had the advantage of the examination of three collections from different parts in the three kingdoms that have been sent to me for the purpose of identification and naming; and have thus some little confidence in approaching the definition of the group. I am well aware that in this, as in all the other groups of coralline remains, there are difficulties that present themselves in their identification, arising from the near affinities of the extreme forms to their nearest ally; and also from the fact

that M'Coy, in his work on Palæozoic Fossils, 1851, asserts that one of the species of the group did belong to the genus *Clisiophyllum* —a statement which I hope I have shown to be untenable when reviewing the latter genus. I was further induced to delay in consequence of M. Edwards and J. Haime having established the genus *Aulophyllum* for another variety. Their type specimen is in the Bristol Museum, but from the fact that this specimen is uncut, and therefore could not be identified with any degree of certainty from the examination I gave it, and from the definitions by these authors in the Trans. of the Palæon. Soc., 1850-4, I am persuaded that the original coral figured by the Rev. D. Ure, in the "History of Rutherglen and East Kilbride," has no generic relation to the genus *Aulophyllum.*

As regards the relationships of the genus, *Cyclophyllum* may be said to be distinguished by characters of an unusually pronounced nature. In some of the passage forms (Pl. XIV., Fig. 5), it is, in one respect, nearly allied to the genus *Rhodophyllum* (Pl. XIV., Fig 12), in the arrangement of the lamellæ in the centre of the visceral chamber, but it is distinctly separated from that genus by the possession of the depression in the crown of the columella presenting the aspect of a double cup; and the columella is always separated from the inner ends of the primary septa by a system of curved plates, which curve and fold round and form the wall of the columella. In *Rhodophyllum* the crown of the columellarian area is dome-shaped, and formed by a system of sub-convolute lamellæ, which fold round an imaginary axis in the centre of the visceral chamber, and the lamellæ arising from the inner ends of the primary septa (Pl. XIV., Fig. 10), have a near affinity to the genus *Cymateophyllum* (Thomson, Pl. XIV., Fig. 16). These are, however, separated from the latter by the possession of the depression in the crown of the columella and the wall that forms its periphery. In Fig. 10 the wall is less dense. The central area is, however, separated from the inner ends of the septa, but is not so pronounced as in all the other species, and so may be regarded as the passage forms of the genus.*

* For a detailed account of the histiological observations regarding the definitions of these different authors that have referred to the group I beg to refer to my paper, published in the *Proceedings* of the Society for 1882.

Cyclophyllum pachyendothecum. (Thomson.)

Plate XIV., Fig. 1.

Specific Characters.—Corallum simple, stout, moderately tall, conical, and curved. The epitheca is thin. The exterior margin of the septa is visible from without through the thin epithecal covering. The calice is shallow and circular, and in its centre the cup is shallow and broad. The septa are stout, and lamellar for four-fifths of their length from their inner ends, and there are nine interlamellar plates in the space of a line, which are the cut ends of the interlamellar striæ, which converge inwards and downwards. The septa are thin towards the periphery. There are seventy-six primary, alternating with an equal number of secondary septa; the latter extend inwards from the periphery for half the length of the primary, and each is united by rectangular interseptal dissepiments, which are dense towards the periphery and few in number in the intermediate ("interlocular") area. The fossula is small, and a portion of the endothecal tissue extends into it. The central area is broad, circular, and accuminate at the mouth of the fossula, and is six lines broad. The endothecal wall is stout. The septa are minute and dense around the periphery. They extend inwards for a line, they then coalesce and become fasciculate, and the central septum of each fascicle extends in towards the central area. They then unite, and form a reticulate cellular tissue in the centre of the central area. The endotheca is united to the inner ends of the primary septa by the intervention of a system of angular plates. The fossula is moderately large, and two of the primary septa, of shorter length than the others, extend into it.

Height of corallum, $2\frac{1}{2}$ inches; diameter of section, 1 inch 4 lines.

Formation.—Lower carboniferous.

Locality.—Found at Brockley, Lesmahagow, Lanarkshire.

Cyclophyllum fungites. (Ure.)

Plate XIV., Fig. 2.

The structural details of the central area of this species differ so widely from the preceding that it is almost unnecessary to do

more then refer to the impression of the plate. This is a *facsimile* of a transverse section of the original specimen figured by the Rev. David Ure in his "History of Rutherglen and East Kilbride," 1793. I have an extensive series of intermediate forms, which clearly show the minute variation of the intervening species. Space will not admit of their introduction into this communication. A number of the varieties may be seen in my paper in the Society's *Proceedings*, 1882. There are at least twelve intervening species between the preceding and this species.

Formation.—Lower carboniferous.

Locality.—Believed to be found in the farm of Shields, East Kilbride, Lanarkshire.

Plate XIV., Fig. 3, is an impression of a longitudinal section of a corallum. The section is cut down the central axis, to show the structural details of an entire corallum and the cup-shaped crown of the tubular columella.

Cyclophyllum concentricum. (Thomson.)

Plate XIV., Fig. 4.

This species is distinguished by the septa of the columellarian area being fewer in number, and they are more or less sinuous and converge to the centre of the central area, and in this respect indicate a divergence from the type or central species, and its mergence to the genus *Cymateophyllum*. It is, however, separated from the latter by the deep groove around the columellarian area, and also by the possession of a distinct wall, which forms the outer boundary of the tubular columella.

Formation.—Lower carboniferous.

Locality.—Found at Gameshill, Dunlop, Ayrshire.

Cyclophyllum curvilineare. (Thomson.)

Plate XIV., Fig. 5.

This remarkable species is distinguished from all the other species by characters of an unusually distinct kind. The septa in the columellarian area are abortive, and may be regarded as a form between the genus *Cyclophyllum* and the genus *Rhodophyllum*

(Pl. XIV., Fig. 12). The septa have all the characteristics of *Cyclophyllum*, as it is only from the structural character of the central area that we can define either genera or species; and, while there is a near affinity in the curviline character of the endothecal tissue to the sub-convolute lamella in *Rhodophyllum*, yet they are separated by characters of a fundamental nature. In *Rhodophyllum* the lamellæ are more or less united to the inner ends of the primary septa, and they curve round an imaginary axis and are united by scarce endothecal tissue, and there is no wall around the columellarian area. While in *Cyclophyllum* there is a more or less broad groove around the columella, there is always an endotheca formed of convex cells, and united to the inner ends of the primary septa by the intervention of a system of plates, and there is always a cycle of septa, more or less dense, around the inner margin of the mural covering. These converge into the centre of the central area, and present a more or less reticulate structure, and I believe upon the whole the structural characters of this species have closer affinities to the latter, and therefore must be placed in that genus. This species also indicates a relationship to the genus *Aulophyllum* by the open space in the centre of the central area, and thus indicates its divergence in opposite directions.

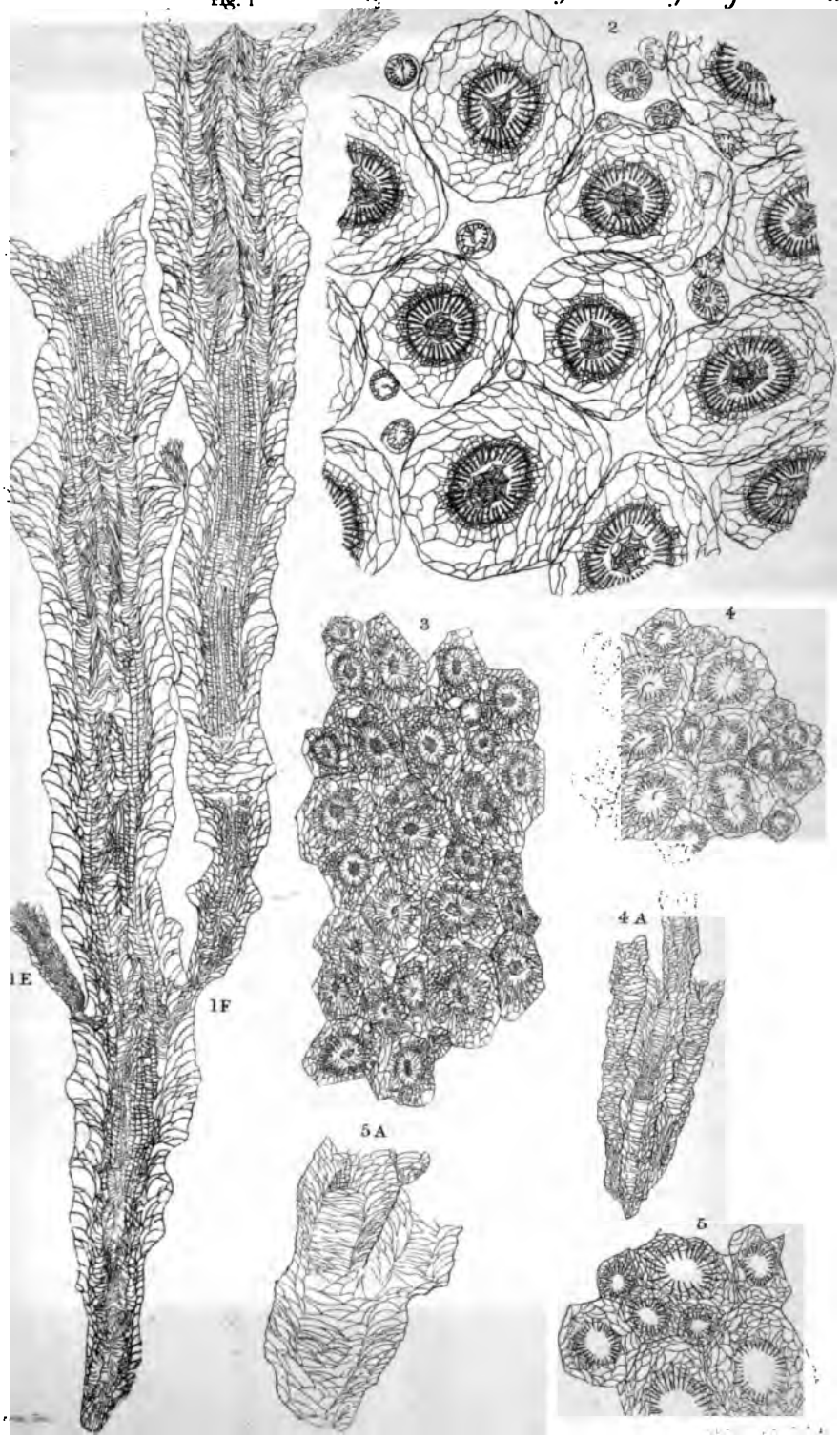
Formation.—Lower carboniferous.

Locality.—Found at Petershill Quarry, Bathgate, Linlithgowshire.

Cyclophyllum paradoxicum. (Thomson.)

Plate XIV., Fig. 10.

This species differs from all the other species of the genus by the form and arrangement of the septa in the columellarian area. In this respect it approximates so near to the structural details of *Cymateophyllum concentricum* on the one hand, and to the genus *Clisiophyllum* on the other, that for a number of years I hesitated as to what genus it really did belong. When, however, I was carefully examining the structural details of the genus *Cyclophyllum*, I was induced to regard it as an intermediate and doubtful species, and, while it indicates a strongly-pronounced divergent character, yet, in the possession of a rudimentary wall around the columellarian area, it may be regarded as a variety of the latter, but whose relationship is remote from the central type, and therefore indicate that its trimorphic character is of a marked nature.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table, and a copy has been sent to each Member of the Society. The Council is confident that a perusal of these Reports will show that, both in the accumulation of facts and in the expression of competent opinion, a valuable contribution has been made to this department of practical science."

7. The Secretary read Reports from the various Sections of the work done during the Session, and these Reports were adopted, and ordered to be printed in the *Proceedings* of the Society.

(Signed) WILLIAM WALLACE.

1st November, 1882.

The Philosophical Society of Glasgow held its first Meeting for Session 1882-3, on the evening of 1st November, 1882, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. William Wallace, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved of, and signed by the Chairman.

2. The following were proposed for election as Members of the Society, viz.:—

Mr. John D. Young, Manager, Scottish Boiler Insurance Company, 162 Buchanan Street. Recommended by Mr. James Paton, F.L.S., Mr. Hazelton R. Robson, and Mr. William Hodge.

Mr. James J. MacLehose, Bookseller, 61 St. Vincent Street. Recommended by Dr. A. B. M'Grigor, Mr. Thomas Muir, M.A., F.R.S.E., and Professor M'Kendrick.

Dr. William L. Reid, 7 Royal Crescent, West. Recommended by Dr. John Burns, Dr. Andrew Fergus, and Dr. James Finlayson.

Mr. W. R. M. Church, C.A., 45 West Nile Street. Recommended by Dr. Andrew Fergus, Mr. J. Cleland Burns, and Dr. J. Christie.

Mr. Charles T. Grant, Gas Coal Merchant, 160 Hope Street. Recommended by Dr. William Wallace, President, Dr. John Clark, and Mr. John Jex Long.

Mr. Alfred R. Bennett, Member of the Society of Telegraph Engineers and of Electricians, 134 Douglas Street. Recommended by Dr. William Wallace, President, Mr. Thomas Muir, M.A., F.R.S.E., and Professor M'Kendrick.

Mr. Samuel MacCall, 16 Hillsborough Square, Ann Street. Recommended by Mr. George Munsie, Dr. Thomas Reid, and Dr. Andrew Fergus.

Mr. Frederick J. Rowan, C.E., 134 St. Vincent Street. Recommended by Dr. Andrew Fergus, Professor M'Kendrick, and Mr. Hazelton R. Robson.

Mr. Duncan M'Naughton, Architect, 91 Hamilton Drive, Hillhead. Recommended by Mr. James Sellars, Jun., I.A., Mr. Hazleton R. Robson, and Professor M'Kendrick.

Mr. Graham James M'Farlane, Manufacturing Chemist, Biltrees, Elderslie. Recommended by Dr. Wallace, President, Dr. John Clark, and Mr. John Tatlock, F.I.C.

3. The President (Dr. Wallace) delivered an Address, illustrated by numerous experiments, on "Chemical Affinity." On the motion of Mr. Michael Connal, V.P., Dr. Wallace was accorded a very hearty vote of thanks.

4. On the motion of the President, Mr. Archibald Hewat, F.F.A., F.S.S., and Mr. Robert Cochran were appointed Auditors of the Treasurer's Accounts for the past year.

(Signed) WILLIAM WALLACE.

15th November, 1882.

The Eighty-first Annual General Meeting of the Philosophical Society of Glasgow, for the Election of Office-bearers and other business, was held on the 15th day of November, 1882, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. William Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were proposed as Members:—

Mr. J. M. Robertson, M.A. (Oxon.), Dentist, 6 Cathedral Street. Recommended by Professor M'Kendrick, Dr. Fergus, and Mr. H. R. Robson.

Mr. Edward Gillespie, Cashier, Cambuslang. Recommended by Dr. Muirhead, Professor M'Kendrick, and Mr. H. R. Robson.

Mr. George H. Laird, Wright, 137 Greenhead Street. Recommended by Mr. George Laird, Mr. John Mann, and Professor M'Kendrick.

Dr. James Whitson, 13 Somerset Place. Recommended by Mr. John Kirsop, Mr. Archibald Robertson, and Mr. John Mann.

Mr. Thomas Miller, Modeller and Plasterer, 138 Wellington Street. Recommended by Mr. A. Lindsay Miller, Mr. John Mann, and Mr. T. L. Watson.

Mr. James A. Paterson, 51 Apsley Place. Recommended by Mr. Stuart Manford, Mr. Peter W. Dixon, and Mr. David Edward.

3. Professor M'Kendrick, Secretary, read the Annual Report by the Council on the state of the Society, which was, on the motion of Mr. W. R. W. Smith, seconded by Mr. Archibald Robertson, adopted, and ordered to be printed in the *Proceedings*. The Report was as follows:—

Report on the State of the Society by the Council for the Session 1881-82.

I. *Membership.*—The number of Members on the Roll at the beginning of Session 1881-82 was 670; during the Session 47 were added, 1 was reinstated from the Suspense List, making 718 in all. Of this number 24 have resigned, 4 have left Glasgow—their names being placed on the Suspense List, 11 have died, and 3 have been struck off the Roll for non-payment of annual subscriptions; leaving on the Roll at the beginning of the present Session, 676 Members, being an increase of 6. Of the 47 new entrants, 7 became Life Members; 3 Ordinary Members also paid the Composition for Life Membership during the Session. 1 Honorary Member, Dr. Andrew Buchanan, has died, leaving 19 Honorary Members, consisting of 6 Foreign, 3 American and Colonial, and 10 British. The Corresponding Members are 4 in number. The total number of Life Members is 44.

II. *Sections.*—The Meetings of the Architectural and Chemical Sections have been well attended, and numerous interesting papers have been read. Six of these appear in the *Proceedings*. The Section for Biology, and the Section for Sanitary and Social Economy have communicated important papers to the General Meetings of the Society, some of which have also appeared in the *Proceedings*. Reference is made to the Reports of the Sections, to be found in the *Proceedings*, Vol. XIII., No. 2, page 618 *et seq.*

III. *The Proceedings.*—The printed *Proceedings* of the Society for 1881-82 contain 20 papers and 13 plates, forming the Second Part of Vol. XIII. The Council begs strongly to urge upon the Members the importance

of communicating to the Society the results of any scientific investigations on which they have been engaged, so as to render the *Proceedings* substantial contributions to Science, and thus to maintain the honour of the Society. In addition, the Council would point out that the interest of the Meetings of the Society would be much enhanced by the exhibition of any specimens of scientific interest, by experiments of a novel character, by showing newly devised apparatus, and by the communication of short papers, not necessarily of an exhaustive character, but marking the progress of any investigation.

IV. *Buildings.*—An Abstract of Accounts, showing the cost of the Buildings, has been sent to the Members along with the Billet calling the present Meeting.

By Order of the Council,

(Signed) JOHN G. M'KENDRICK,
Secretary to the Society.

4. The Audited Statement of Accounts for Session 1881-82, by Mr. John Mann, the Treasurer, having been printed in the circular calling the Meeting, was held as read, was approved of, and was ordered to be printed in the *Proceedings*. A vote of thanks to the Treasurer was carried unanimously.

Dr. ABSTRACT OF TREASURER'S

1882.—Oct. 31.								
To Entry-money from 47 New Members, at 21s.,				£49	7	0		
,, Annual Dues from 1 Member for 1878-79, at 21s., . .	£1	1	0					
,, Annual Dues from 3 Members for 1879-80, at 21s., . .	3	3	0					
,, Annual Dues from 4 Members for 1880-81, at 21s., . .	4	4	0					
,, Annual Dues from 613 Ordinary Members for 1881-82, at 21s.,	643	13	0					
,, Annual Dues from 40 New Members for 1881-82, at 21s.,	42	0	0					
				694	1	0		
,, Life Subscription from 7 New Members, at £10 10s., .	£73	10	0					
,, Life Subscription from 3 Old Members, at £10 10s., .	31	10	0					
				105	0	0		
							£848	8 0
,, CHEMICAL SECTION—								
2 Associates for 1879-80, at 5s., . .				£0	10	0		
8 do. 1880-81, at 5s., . .				2	0	0		
37 do. 1881-82, at 5s., . .				9	5	0		
							11	15 0
,, ARCHITECTURAL SECTION—								
37 Associates' fees between 18th March, 1881, and 16th March, 1882, at 5s., ...							9	5 0
,, Corporation of Glasgow, Interest on "Exhibition Fund" for year to Whitsunday, 1882—less Income Tax, .							47	18 8
,, *Proceedings*, &c., sold, ...							0	16 6½
,, LATE BOTANICAL SECTION—								
Balance of its Funds, placed at the disposal of the Society by Mr. John Alexander, Mr. Michael Connal, and Mr. Robert Balloch, the surviving Members of the Section, ...							5	18 2
							£924	1 4½

GLASGOW, *8th November, 1882.*—We, the Auditors appointed by the examined the same, of which the above is an Abstract, and have found them

Limited, Seventy Pounds, and in Treasurer's hands Two Pounds Twelve

Memo. by Treasurer.—The Amount of the Society's Funds invested in the Bath Street Joint Buildings up to 31st October, 1882, is £3,500 1s. 11d., of which, Paid in Cash from Society's Funds, £1,500 1 11

Do. do. from Private Loans, . 500 0 0

Do. from Society's half of £3,000 Bond over Buildings, . . 1,500 0 0

£3,500 1 11

J. M.

ACCOUNT—SESSION 1881-82. **Cr.**

1881.—Nov. 1.						
By Balance due Treasurer from last Session,					£109	9 11
1882.—Oct. 31.						
By Salary to Secretary,		£75	0	0		
,, Allowance for Treasurer's Clerks,		15	0	0		
,, Demonstrations at Lectures,		3	6	4		
					93	6 4
,, New Books, Periodicals, and Foreign Periodicals,		£112	1	11		
,, Printing Circulars, *Proceedings*, &c.,		153	0	0		
,, Lithographs for *Proceedings*, &c., £31 14s. 6d.; Woodcuts, £5 10s.,		37	4	6		
,, Postage and delivery of Circulars, Letters, and Parcels,		34	10	1		
,, Stationery,		8	6	6		
		£345	3	0		
Less, Contributions by Authors to cost of Illustrations,		0	4	0		
					344	19 0
,, Fire Insurance on Library for £5,400,		£5	18	0		
,, Postages, &c.—per Treasurer, £1 11s. 7½d.; per Secretary, £6 2s. 10d.,		7	14	5½		
,, Sundries in Library,		0	17	5		
,, Interest on Loans,		25	0	0		
					39	9 10½
,, SUBSCRIPTIONS TO SOCIETIES—						
Ray Society, 1882,		£1	1	0		
Palæontographical Society, 1882,		1	1	0		
					2	2 0
,, CHEMICAL SECTION— Expenses per Treasurer of Section,					6	15 3
,, ARCHITECTURAL SECTION— Expenses per Treasurer of Section,					3	2 11
,, BATH STREET JOINT BUILDINGS— Society's half of Balance of Accounts,					145	1 11
,, JOINT EXPENSES OF ROOMS— Society's half of Interest on Bond, Taxes, Cleaning, Lighting, and Heating, Salaries of Sub-Librarian and Assistant—less half of Revenue from Letting,					107	2 1
,, Clydesdale Bank, Limited, Lodged,					70	0 0
,, Balance in Treasurer's hands,					2	12 1
					£924	1 4½

Society to examine the Treasurer's Accounts, for the year 1881-82, have correct, the Balances at 31st October last being—in Clydesdale Bank, Shillings and One Penny.

(Signed) ARCH. HEWAT.
ROBERT COCHRAN.

5. Mr. John Robertson, Librarian, and Convener of the Library Committee, read the Annual Report on the Library, which was adopted, and ordered to be printed in the *Proceedings*. The Report was as follows :—

REPORT OF THE LIBRARY COMMITTEE.

Your Committee have to report that books were issued during the past year to 826 members. Considerable advantage was taken of the Library for the purposes of reference and consulation.

Since last Report 196 volumes, 46 parts of works, and 14 pamphlets have been added to the Library. Of the periodicals received 22 are weekly, of which 18 are bought and 4 presented ; 3 are fortnightly, of which 2 are bought and 1 presented ; 38 are monthly, of which 28 are bought and 10 presented ; and 21 are quarterly, of which 15 are bought and 6 presented. These form 128 volumes a year.

Exchanges of *Transactions* and other Publications are made with 121 Societies and Public Departments. Correspondence has been opened up with the Insurance and Actuarial Society of Glasgow and the Ohio Mechanics' Institute.

For financial reasons fewer books than formerly have been bought during the past year. 131 volumes were added to the Library by purchase ; 65 volumes, 46 parts, and 14 pamphlets were presented, and the thanks of the Society are due to the donors. Acknowledgment of these will be found in the *Proceedings*, where a complete list of the additions for the year, and of the names of the Societies and Public Departments with which publications are exchanged, has been printed.

176 volumes have been bound and 27 are in the hands of the binder.

The new Catalogue has been printed and awaits binding. It will be ready for the use of members immediately.

(Signed) JOHN ROBERTSON,
Convener.

A special vote of thanks, on the motion of Mr. Archibald Robertson, seconded by Mr. Thomas Muir, was unanimously given to the Librarian for the great labour he has expended on the Library, more especially in the preparation of the Catalogue.

6. The Society then proceeded to the election of Office-bearers.

(1) Mr. Thomas Muir, the Vice-President, retiring by rotation, proposed for the office of Vice-President James B. Russell, B.A., M.D. This was seconded by Mr. W. R. W. Smith, and was carried with acclamation.

(2) On the motion of the President, Mr. John Robertson, Librarian, Mr. John Mann, Treasurer, and Professor M'Kendrick, Secretary, were unanimously re-elected to their respective offices for the present year.

(3) The President stated that five new Members of Council were required in room of Mr. John Jex Long, Dr. Eben. Watson, Mr. James Brownlie, and Mr. William Foulis, C.E., who retire by rotation, and of Mr. James Thomson, who had been elected President of the Biological Section.

It was moved by Mr. J. Jex Long, and seconded by Mr. Alexander Scott, that Mr. Archibald Robertson, Mr. Archibald Hewat, and Dr. James Morton be elected Members of Council. Mr. Alexander Scott moved, and Mr. James Thomson seconded, Dr. James Stirton as a Member of Council. Mr. D. M. Nelson proposed, and Mr. W. R. W. Smith seconded, Dr. Henry Muirhead as a Member of Council.

The Society then balloted for five Members of Council, Mr. John Mayer, F.C.S., and Mr. John Jex Long having been appointed scrutineers. The scrutineers reported that the following had the greatest number of votes:—Dr. Henry Muirhead, 45; Dr. Thomas Muir, 44; Dr. Morton, 42; Dr. Stirton, 40; and Mr. Archibald Robertson, 37. These gentlemen were therefore declared by the Chairman to have been duly elected Members of Council—Mr. Archibald Robertson being in the place of Mr. James Thomson, F.G.S., who had become President of the Biological Section.

7. Dr. John Dougall read a paper on "Milk and Milk Pollution," forwarded from the Sanitary Section. After an interesting discussion, Dr. Dougall was awarded a vote of thanks.

8. Dr. Wallace read a paper on "Insensibility Arising from a Diminished Quantity of Oxygen in the Air," which he illustrated by an experiment showing the great absorption of oxygen by a "rusting" composition used in the construction of cylinders often employed in the building of bridges. Dr. Wallace was awarded a vote of thanks for his important communication.

(Signed) WILLIAM WALLACE.

29th November, 1882.

The Second General Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 29th day of November, 1882, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. William Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were admitted Members of the Society :—

Mr. John D. Young; Mr. James J. MacLehose, M.A.; William L. Reid, M.D.; Mr. W. R. M. Church; Mr. Charles T. Grant; Mr. Alfred R. Bennett; Mr. Samuel MacCall; Mr. Frederick J. Rowan; Mr. Duncan M'Naughton; Mr. Graham James M'Farlane.

3. The following were proposed as Members :—

Mr. W. N. Baronsfeather, 7 Berlin Terrace, Pollokshields. Recommended by Mr. H. D. Gillies, Mr. Archibald Robertson, and Mr. John Mann.

Mr. Thomas Ferguson, Boilermaker, Parkhead. Recommended by Mr. J. S. MacGill, Mr. David Maclure, and Mr. John Mann.

Mr. Alexander Muir, Builder, 65 Eglinton Street. Recommended by Mr. T. L. Watson, Mr. David Thomson, and Mr. A. Lindsay Miller.

4. Sir William Thomson made a communication to the Society entitled "Approximative Photometric Measurements of Sun, Moon, Cloudy Sky, Electric, and other Artificial Lights," for which he received the thanks of the Society.

5. The President announced that the following gentlemen had been duly elected by ballot as Members of the Society :—

Mr. John M. Robertson, M.A. (Oxon.), Mr. Edward Gillespie, Mr. George H. Laird, Dr. James Whitson, Mr. Thomas Miller, and Mr. James A. Paterson.

(Signed) MICHAEL CONNAL.

6th December, 1882.

A Special Meeting of the Society was held in the Rooms of the Society, on Wednesday, the 6th of December, 1882, at eight o'clock p.m. (Dr. Wallace in the Chair), when Dr. Eben. Duncan read a paper "On the Clauses in the Draft Glasgow Police Bill which have reference to the Prevention and Mitigation of Disease." After some discussion, in which Professor Gairdner, Dr. Russell, and Mr. Alexander Scott took part, the following motion was moved by Professor M'Kendrick, and seconded by Mr. John Mayer, "That Dr. Duncan's Paper be printed, and a copy of it sent to each Member of the Society and to Members of the Town Council; that the discussion be adjourned to a special Meeting to be held on Wednesday, 20th December, and that suitable arrangements be made for reporting the discussion on that occasion." The motion was carried, and, on the suggestion of the President, it was agreed to invite the Members of the Town Council to the Meeting on 20th December.

(Signed) WILLIAM WALLACE.

13th December, 1882.

The Third Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 13th day of December, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street —Mr. Michael Connal, Vice-President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were admitted Members of the Society:—

Mr. J. A. Robertson, M.A. (Oxon.), Dentist, 6 Cathedral Street; Mr. Edward Gillespie, Cashier, Cambuslang; Mr. George H. Laird, Wright, 137 Greenhead Street; Dr. James Whitson, 13 Somerset Place; Mr. Thomas Miller, Modeller and Plasterer, 138 Wellington Street; and Mr. James A. Paterson, 51 Apsley Place.

3. The following were proposed as Members:—

Mr. William Salvador Curphey, 1 Albany Place. Recommended by Professor W. Dittmar, Mr. C. A. Fawsett, and Professor J. Blyth.

Mr. John Knox, Coke Manufacturer, 25 Bath Street. Recommended by Mr. W. R. Hutton, Dr. Wallace, and Mr. John Mayer.

Mr. David Terrace, Gas Manager, Dawsholm Gas-works, Maryhill. Recommended by Dr. Wallace, Mr. William Foulis, and Mr. John Clark.

Mr. William Thomson, Brushmaker, 75 Stockwell Street. Recommended by Mr. Wallace Fairweather, C.E., Mr. Archibald Robertson, and Professor M'Kendrick.

Mr. E. M. Dixon, B.Sc., read a paper, prepared by himself and Mr. David Sandeman, entitled "The Relation of the School to the Workshop." After some remarks by Mr. Sandeman, a discussion took place, and, on the motion of the Chairman, a cordial vote of thanks was given to the authors of the paper.

5. The Chairman announced that the following gentlemen had been duly elected by ballot to the Membership of the Society:—

Mr. W. N. Baronsfeather, 7 Berlin Terrace, Pollokshields; Mr. Thomas Ferguson, Boilermaker, Parkhead; and Mr. Alexander Muir, Builder, 63 Eglinton Street.

(Signed) WILLIAM WALLACE.

17th January, 1883.

The Fourth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-3 was held on the evening of 17th January, at eight o'clock, in the Rooms of the Society, 207 Bath Street—Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were admitted Members of the Society:—

Mr. W. N. Baronsfeather, 7 Berlin Terrace, Pollokshields; Mr. Thomas Ferguson, Boilermaker, Parkhead; and Mr. Alexander Muir, Builder, 65 Eglinton Street.

3. The following were proposed as Members :—

Mr. Peter Gibb, Merchant, 10 Granby Terrace. Recommended by Mr. W. R. W. Smith, Mr. Daniel Munro, and Mr. John Mann.

Mr. James P. M'Gillivray, Artist, 112 Bath Street. Recommended by Mr. Robert Turnbull, I.A., Mr. A. Lindsay Miller, and Mr. T. L. Watson, I.A.

Mr. James A. Morrice, Manufacturing Chemist, Tullymet, Aytoun Road, Pollokshields. Recommended by Mr. R. R. Tatlock, Dr. Wallace, and Professor M'Kendrick.

Dr. Robert Pollock, Tradeston House, Pollokshields. Recommended by Dr. James Morton, Dr. M'Call Anderson, and Dr. Eben. Watson.

Mr. Rees Price, L.D.S.Eng., Dental Surgeon, 1 Montague Place, Bath Street. Recommended by Mr. A. Robertson, Professor M'Kendrick, and Mr. J. J. Coleman, F.C.S.

4. Mr. J. J. Coleman, F.C.S., read a paper "On the Preserva tion of Food by Cold," for which he received the thanks of the Society. The paper was illustrated by numerous diagrams.

5. Professor M'Kendrick exhibited and explained a simple form of Lippmann's Electrometer, made by him. The movements of the mercurial column were projected on the screen by a lime light.

6. The Chairman announced that the following gentlemen had been duly elected by ballot to the Membershsp of the Society:— Mr. William Salvador Curphey, 1 Albany Place; Mr. John Knox, Coke Manufacturer, 25 Bath Street; Mr. David Terrace, Gas Manager, Dawsholm Gas-works, Maryhill; and Mr. William Thomson, Brushmaker, 75 Stockwell Street.

(Signed) WILLIAM WALLACE.

20th December, 1882.

In accordance with a resolution passed at a Special Meeting of the Society on 6th December, a second Special Meeting (to which Members of the Town Council of Glasgow had received a special invitation) was held in the Rooms of the Society, on Wednesday evening, 20th December, at eight p.m.—Dr. Wallace in the Chair.

1. The Minutes of the Special Meeting on 6th December were read, approved of, and signed by Dr. Wallace.

2. The discussion was resumed on Dr. Eben. Duncan's paper, entitled "On the Clauses in the Draft Glasgow Police Bill which have reference to the Prevention and Mitigation of Disease."

After an interesting discussion, in which Dr. J. B. Russell, Dr. Fergus, Preceptor Mathieson, Dr. Eben. Watson, Dr. Morton, Mr. J. Cleland Burns, Dr. James Christie, Professor M'Call Anderson, Mr. D. M. Nelson, the President, and Dr. Eben. Duncan took part, Dr. Duncan, on the motion of the President, received a cordial vote of thanks.

(Signed) WILLIAM WALLACE.

31st January, 1883.

The Fifth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the evening of 31st January, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were admitted Members of the Society:—

Mr. Salvador Curphey, 1 Albany Place; Mr. John Knox, Coke Manufacturer, 25 Bath Street; Mr. David Terrace, Gas Manager, Dawsholm Gas-works, Maryhill; and Mr. William Thomson, Brushmaker, 75 Stockwell Street.

3. Mr. Wallace Fairweather, C.E., read a paper "On Struthers' Process for Pulverizing Diamondiferous Ore." After some remarks by Mr. Struthers, he and Mr. Fairweather were awarded a vote of thanks for the communication.

4. Mr. A. C. Weir, introduced by Professor M'Kendrick, read a paper "On the Physiology of Articulate Speech," for which he received the thanks of the Society.

5. Mr. William Milne, M.A., B.Sc., read a paper describing some New Infusoria, for which he received the thanks of the Society.

6. The President announced that the following gentlemen had been duly elected by ballot to the Membership of the Society:—

Mr. Peter Gibb, Merchant, 10 Granby Terrace; Mr. James P. M'Gillivray, Artist, 112 Bath Street; Mr. James A. Morrice, Manufacturing Chemist, Tullymet, Aytoun Road, Pollokshields; Dr. Robert Pollock, Tradeston House, Pollokshields; Mr. Rees Price, L.D.S.Eng., Dental Surgeon, 1 Montague Place, Bath Street.

7. The President announced that, on the recommendation of the Council, Principal Dawson, LL.D., Macgill College, Montreal, had been elected to the vacancy in the list of Honorary Members.

8. The President announced that the following gentlemen, on the recommendation of the Council, had been elected Corresponding Members of the Society:—

John Aitken, F.R.S.E., Darroch, Falkirk; Alexander Buchan, M.A., F.R.S.E., Secretary to the Meteorological Society of Scotland, Edinburgh; James Dewar, M.A., F.R.S., L. and E., Jacksonian Professor of Chemistry in the University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain; Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeon's Hall, Edinburgh; Joseph Swan, Newcastle and London; E. A. Wünsch, F.G.S., Glasgow.

(Signed) WILLIAM WALLACE.

14th February, 1883.

The Sixth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 14th day of February, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street —Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The following were admitted Members of the Society:—

Mr. Peter Gibb, Merchant, 10 Granby Terrace; Mr. James P. M'Gillivray, Artist, 112 Bath Street; Mr. James A. Morrice, Manufacturing Chemist, Tullymet, Aytoun Road, Pollokshields; Dr. Robert Pollock, Tradeston House, Pollokshields; Mr. Rees Price, L.D.S.Eng., Dental Surgeon, 1 Montague Place, Bath Street.

3. Professor M'Kendrick announced that the gentlemen elected as Corresponding Members at last Meeting had accepted of the honour, and had tendered their thanks to the Society.

4. Mr. George C. Thomson, Engineer, 77 Hill Street, Garnethill, was proposed for the Membership of the Society on the recommendation of Mr. John L. Bruce, Mr. David Sturrock, and Mr. John Mann.

5. Mr. Nathaniel Dunlop read a paper "On Ships, Ancient and Modern; with special reference to the Applications of Science in their Structure and Outfit." The paper was illustrated by numerous diagrams, specimens, pieces of apparatus, and models. On the motion of Professor Jack, a cordial vote of thanks was awarded to Mr. Dunlop.

(Signed) MICHAEL CONNAL.

28th February, 1883.

The Seventh Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 28th day of February, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street —Mr. Michael Connal, Vice-President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. Professor M'Kendrick announced that Principal Dawson, Macgill College, Montreal, recently elected as an Honorary Member, had accepted of the honour, and had tendered his thanks to the Society.

3. Mr. Charles J. Clark, on the introduction of Sir William Thomson, read a paper "On Induction Intensity Coils, Portable Batteries, and Electric Lights." He showed specimens of small and powerful batteries, a new method of making small induction coils, and an ingenious apparatus for lighting gas by electricity, After remarks by Sir W. Thomson and others, a cordial vote of thanks was awarded to Mr. Clark.

4. Mr. Thomas Gray, B.Sc., on the introduction of Sir William Thomson, exhibited and described "A new Seismographic Apparatus for recording the time of occurrence of, and the horizontal and vertical motion during, an Earthquake." Mr. Gray was awarded a vote of thanks.

5. The Chairman announced that Mr. Charles C. Thomson, Engineer, 77 Hill Street, Garnethill, had been duly elected an Ordinary Member of the Society.

(Signed) WILLIAM WALLACE.

14th March, 1883.

The Eighth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 14th day of March, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street —Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. Mr. George C. Thomson, Engineer, 77 Hill Street, Garnethill, was admitted a Member of the Society.

3. Mr. James Thomson, F.G.S., delivered an address, as President of the Biological Section, on "The Development and Generic Relations of the Carboniferous Corals." The paper was illustrated by numerous photographs of sections of corals projected on the screen by the lime-light. Mr. Thomson received the thanks of the Society for his address.

4. The following extract from the Minutes of Council was read. From Minute of Meeting of Council of date 10th January, 1883 :—

> "A remit from the Society, of date 1st March, 1882, was considered, "and, on the motion of Dr. Wallace, it was unanimously agreed "that it is inexpedient to make a permanent arrangement to have "all discussions at the Meetings of the Society reported, and that "it be left to the discretion of the Council to engage a Reporter "when they deem it advisable."

5. Mr. Alexander Scott gave notice that he would move, at next General Meeting, that steps be taken toward the formation of a Geographical and Ethnological Section of the Society.

(Signed) WILLIAM WALLACE.

28th March, 1883.

The Ninth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 28th day of March, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street —Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The Rev. J. E. Carlyle read a paper prepared by Mr. James Stevenson, F.R.G.S., entitled "The Water Highways of Central Africa." The paper was illustrated by maps, and in particular by a splendid new map prepared for Mr. Stevenson by Mr. E. G. Ravenstein. After some remarks by Mr. Ewing, Mr. Muir, and Dr. Christie, Mr. Carlyle was requested to convey to Mr. Stevenson the cordial thanks of the Society. Mr. Carlyle stated that, if a Section of the Society for Geography and Ethnology were founded, as was proposed, Mr. Stevenson would present to it the new map of Africa prepared to illustrate the paper. The President tendered the thanks of the Society to Mr. Stevenson for his valuable gift.

3. Mr. Alexander Scott moved, and Mr. Thomas Muir seconded, "That steps be taken towards the formation of a Geographical and Ethnological Section." The motion was unanimously adopted.

4. Mr. Alexander Scott moved, and Dr. Christie seconded, "That the following gentlemen be appointed as a Committee to draw up a Constitution and Rules for the proposed Section, and to lay before the Society, at an early date, the names of the first Office-bearers:—Mr. James Stevenson, Mr. Thomas Muir, Mr. Michael Connal, Dr. Christie, and Mr. Alexander Scott—Mr. Scott, Convener." The motion was unanimously adopted.

5. The Society received the following Report from the Sanitary and Social Economy Section regarding the amendment of the Public Health (Scotland) Act, 1867:—After some discussion, on the motion of the President, seconded by Dr. Christie (President of the Sanitary and Social Economy Section), the Report was referred to the Council, with the view of determining what further steps should be taken in the matter.

6. Mr. John Mayer, F.C.S., gave notice that, at next Meeting of the Society, he would move—"That the Society vote a sum of not exceeding twenty pounds, in aid of a fund for erecting a Meteorological Observatory on Ben Nevis."

REPORT OF THE COMMITTEE APPOINTED TO PREPARE A DRAFT CONSTITUTION, &c., FOR THE PROPOSED GEOGRAPHICAL AND ETHNOLOGICAL SECTION.

The Committee recommend as follows:—

(1) The object of the Section shall be to aid the advancement of Geography and Ethnology, by affording opportunity for the discussion of subjects related thereto—to be introduced by the reading of papers or by verbal communications. The general aim shall be to have the papers read before the Society; but the Section may have separate Meetings for that purpose when, in the opinion of the Council of the Section, it is deemed desirable.

(2) The Section shall consist of Members of the Philosophical Society—who are to be admitted free to its meetings; and of Associates who are not Members of the Philosophical Society—who shall be admitted to the Section on payment of an annual subscription of five shillings. Associates to have the privilege of attending not only the Section's meetings, but also those meetings

of the Society at which the Section's papers are read or discussed, and also of consulting the books in the Library.

(3) The Management of the Section shall devolve upon a Council, consisting of a President, three Vice-Presidents, a Secretary (who shall also act as Treasurer), and nine other Members.

(4) The term of office of Members of Council shall be three years, except in the case of the Secretary, who shall be elected annually. Retiring Members shall be eligible for re-election. Three shall be a quorum.

(5) The Office-bearers of the Section shall be elected by the Society, at its Annual Business Meeting.

(6) Vacancies occurring during the currency of a year may be filled up, *ad interim*, by the Council, if they deem it expedient.

(7) The Council of the Section shall report annually to the Society.

(8) No paper shall be read which has not been approved of by the Council; and copies of the paper read shall be given into the charge of the Secretary of the Society, or the Secretary of the Section, as the case may be.

(9) Associates shall be elected by the Council at any of its meetings. Each Candidate shall be recommended by two Members or Associates. The vote shall be by ballot, a majority deciding.

(10.) The Associates' annual subscription shall become due on the first day of November in each year.

(11.) No alteration shall be made upon the foregoing without the consent of the Society at two successive Ordinary Meetings.

The Committee further suggest that, in the meantime, only six of the Members of Council be elected—the remainder to be elected at the Business Meeting in November next; and that, considering that the present Session is so far advanced, the period from this date to the Annual Meeting in November, 1884, be, for all the purposes of the Section, deemed one year.

ALEX. SCOTT,
Convener.

(Signed) WILLIAM WALLACE.

11th April, 1883.

The Tenth Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 11th day of April, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed and signed by the Chairman.

2. The Rev. A. S. Wilson, M.A., B.Sc., Professor of Botany in Anderson's College, read a paper on "The Fertilisation of Flowers." The paper was illustrated by numerous diagrams and by specimens. Mr. Wilson received the cordial thanks of the Society.

3. Mr. Alexander Scott laid before the Society the following Report of the Committee appointed at last Meeting, regarding the Geographical and Ethnological Section:—

REPORT OF THE COMMITTEE APPOINTED TO PREPARE A DRAFT CONSTITUTION, &C., FOR THE PROPOSED GEOGRAPHICAL AND ETHNOLOGICAL SECTION.

The Committee recommend as follows:—

(1) The object of the Section shall be to aid the advancement of geography and ethnology, by affording opportunity for the discussion of subjects related thereto—to be introduced by the reading of papers or by verbal communications. The general aim shall be to have the papers read before the Society; but the Section may have separate meetings for that purpose when, in the opinion of the Council of the Section, it is deemed desirable.

(2) The Section shall consist of Members of the Philosophical Society—who ars to be admitted free to its meetings; and of Associates who are not Members of the Philosophical Society—who shall be admitted to the Section on payment of an annual subscription of five shillings. Associates to have the privilege of attending not only the Section's meetings, but also those meetings of the Society at which the Section's papers are read or discussed; and also of consulting the books in the Library.

(3) The Management of the Section shall devolve upon a Council, consisting of a President, three Vice-Presidents, a Secretary (who shall also act as Treasurer), and nine other Members.

(4) The term of office of Members of Council shall be three years, except in the case of the Secretary, who shall be elected annually. Retiring Members shall be eligible for re-election. Three shall be a quorum.

(5) The Office-bearers of the Section shall be elected by the Society at its Annual Business Meeting.

(6) Vacancies occurring during the currency of a year may be filled up, *ad interim*, by the Council, if they deem it expedient.

(7) The Council of the Section shall report annually to the Society.

(8) No paper shall be read which has not been approved of by the Council; and copies of the paper read shall be given into the charge of the Secretary of the Society, or the Secretary of the Section, as the case may be.

(9) Associates shall be elected by the Council at any of its meetings. Each candidate shall be recommended by two Members or Associates. The vote shall be by ballot, a majority deciding.

(10) The Associates' annual subscription shall become due on the first day of November in each year.

(11) No alteration shall be made upon the foregoing without the consent of the Society, at two successive Ordinary Meetings.

The Committee further suggest that in the meantime, only six of the Members of Council be elected—the remainder to be elected at the Business Meeting in November next; and that, considering that the present Session is so far advanced, the period from this date to the Annual Meeting in November, 1884, be, for all the purposes of the Section, deemed one year.

ALEX. SCOTT,
Convener.

Mr. Scott moved, and Dr. Henry Muirhead seconded, the adoption of the Report. This was unanimously agreed to, and a Geographical and Ethnological Section was accordingly constituted, subject to the rules embodied in the Report.

4. Mr. Alexander Scott, on behalf of the Committee, moved that the following gentlemen be appointed Office-bearers of the Geographical and Ethnological Section until the Annual Meeting of the Society in November next:—Dr. W. G. Blackie, F.R.G.S.; Mr. James Stevenson, F.R.G.S.; Mr. Michael Connal, Mr. Thomas Muir, M.A.; Mr. James Grierson, and Dr. James Christie—Dr. Christie being requested to act as Secretary *pro tempore*. This

motion was seconded by Mr. Archibald Robertson, and was unanimously adopted.

5. The Secretary read the following Report from the Council:—

Extract Minute of Council, dated 4th April, 1883.—The Council considered the Report from the Sanitary and Social Economy Section regarding the amendment of the Public Health (Scotland) Act, 1867, remitted to them by the Society on 28th March, and resolved to advise the Society to adopt the Report, and to petition the proper authorities, in terms of the recommendations contained in the Report.

On the motion of the President, the Society followed the advice of the Council, and adopted the Report; and the Secretary was instructed to prepare and print in next Billet a Memorial or Petition to that effect, addressed to the Right Hon. the Earl of Rosebery, Under-Secretary of State, and to the Right Hon. the Lord Advocate for Scotland.

6. The motion in the name of Mr. John Mayer fell to the ground, in consequence of the absence of the proposer.

(Signed) WILLIAM WALLACE.

The Society held another Meeting on 25th April, 1883, when Mr. R. R. Tatlock read a paper prepared by Mr. George MacRoberts, F.C.S., Nobel's Explosives Company, Ardeer. Reports were given in from the various Sections. The Committee on Patents was reappointed. Memorials regarding the amendment of the Public Health (Scotland) Act, 1867, to the Earl of Rosebery and the Lord Advocate, were approved of, and were ordered to be forwarded. Dr. Henry Muirhead and Professor M'Kendrick were appointed Delegates from the Society to the Meeting of the British Association at Southport in September, 1883. Mr. John Mayer gave notice of a motion regarding a subscription to the Ben Nevis Observatory Fund. The Minutes of this Meeting, if approved, will appear in next volume of the *Proceedings*.

(Signed) WILLIAM WALLACE.

MEMORIALS REGARDING THE AMENDMENT OF THE PUBLIC HEALTH (SCOTLAND) ACT, 1867.

To The Right Hon. The Earl of Rosebery,
Under-Secretary of State for Scotland—

THE MEMORIAL OF THE PHILOSOPHICAL SOCIETY OF GLASGOW.

The Philosophical Society of Glasgow, now holding its Eightieth Session, consists of nearly 700 Members, representing the professions, and the arts, manufactures, trade, and commerce of the City of Glasgow. The Philosophical Society has a Section for the special consideration of matters relating to Sanitary and Social Economy, many of the Members of which have had large experience in practical hygiene.

That the Society, both in its Sanitary and Social Economy Section and in General Meetings, has had under consideration the amendment of the Public Health (Scotland) Act, 1867, and, as the result of its deliberations, has resolved humbly to make the following suggestions to your Lordship, in the hope that they may be favourably considered by the Government in impending legislative measures as to public health :—

I. With reference to the Administrative and Executive Machinery of the Health Act, the Society is of opinion—

(1) That the best Central Health Authority for Scotland would be a separate Board of Health, under the presidency of the Under-Secretary of State for Scotland, and having as members representatives of the legal, medical, and engineering professions; but if, looking to the amalgamation of Poor-Law and Health under Central Boards in the sister kingdoms, this scheme is found impracticable, the Board of Supervision should be modified by the addition of similar representatives—in either case one medical gentleman who has given special attention to Public Health matters to be a paid member of the Board, and to devote his whole time to the duties of his office;

(2) That it is desirable that extensive controlling powers should be given to the Central Authority, and that a staff of Officers should be appointed under it;

(3) That the Central Authority should be empowered and required to divide the whole country into Health Districts;

(4) That, in the formation of these Health Districts, the areas of existing Local Authorities, whether urban or rural, should be combined according to grouping of population, circumstances of common drainage and water supply, or any other circumstances which the Central Authority, after due inquiry, consider of importance in determining the boundaries of the Health District; wholly irrespective of County or other existing boundaries;

(5) That each existing Local Authority should have representation in a Central Health Board to be constituted for the District of which it is a unit;

(6) That each Health District should have a Medical Officer of Health, whose work should be wholly confined to the duties of his office —the salary to be fixed by the Central Authority, and the officer irremovable except with the consent of the same Authority; and

(7) That a Staff should be under his direction and control, whose work should also be confined to the duties of their respective offices, and their remuneration fixed by the Central Authority.

II. As regards the subject-matter of the Law, the Society approves generally the provisions of the Irish Public Health Act, with the following additions :—

Clauses embodying—

1st. Compulsory Notification of Infectious Diseases.
2nd. The Regulation of the Milk Supply.
3rd. Compulsory Hospital Accommodation for Infectious Diseases in every Health District.
4th. More stringent Regulations with regard to Overcrowding and Lodging-houses.
5th. Additional Powers to Sanitary Inspectors for the Summary Removal of Nuisances.

The Society would further respectfully recommend that all duties under the Vaccination Acts should be transferred from the Parochial to the District Health Boards, and that detailed Building Regulations be prescribed by the proposed General Public Health Act, or by a separate Building Act.

Signed and sealed on behalf of the Society by

L. S.

WILLIAM WALLACE, *President.*

JOHN G. M'KENDRICK, *Secretary.*

3rd May, 1883.

A Memorial to The Right Hon. The Lord Advocate for Scotland was in the same terms.

The following replies have been received to the foregoing Memorial:—

(1) FROM THE EARL OF ROSEBERY.

SECRETARY OF STATE,
HOME DEPARTMENT, *8th May*, 1883.

DEAR SIR,—Lord Rosebery desires me to acknowledge your letter of the 4th inst., and in reply to say that he will lay the Memorial from the Philosophical Society of Glasgow, therein enclosed, before the Secretary of State for his consideration.

I am, Dear Sir,
Yours faithfully,
WM. C. DUNBAR.

J. G. M'KENDRICK, Esq.

(2) FROM THE LORD ADVOCATE.

LORD ADVOCATE'S CHAMBERS, HOME OFFICE,
LONDON, WHITEHALL, S.W., *7th May*, 1883.

DEAR SIR,—I am directed by the Lord Advocate to acknowledge receipt of your letter of 4th inst., enclosing a Memorial for the Philosophical Society of Glasgow, regarding the Public Health Act, 1867, which will receive careful consideration.

I am,

Yours faithfully,

D. CRAWFORD.

Professor M'KENDRICK, M.D.

REPORT OF THE ARCHITECTURAL SECTION OF THE GLASGOW PHILOSOPHICAL SOCIETY, FOR SESSION 1882-83.

During the Session eight Meetings have been held. The follow- is a list of papers read at those Meetings:—

November 13, 1882.—John Dansken, Esq., Measurer, read a paper on "Building Construction: Suggestions for Protection from Fire."

November 27, 1882.—John Hay, Esq., Heating and Ventilating Engineer, read a paper entitled "Ventilation Considered in Relation to the Opposite Seasons of the Year."

December 11, 1882.—John Goldie, Esq., Builder, read a paper on "Brick-making and Brick-building."

January 15, 1883.—C. P. Hogg, Esq., C.E., read a paper on "Foundations."

January 29, 1883.—Dr. William Wallace, President of the Philosophical Society, read a paper on "The Decay of Building Stones."

February 26, 1883.—John Honeyman, Esq., Architect, read a paper on the "Proposed Removal of St. George's Church;" and T. L. Watson, Esq., Architect, read a paper on "Square Dressed Rubble."

March 12, 1883.—William Landless, Esq., Architect, read a paper entitled "The Rival Cities."

March 26, 1883.—John Cowan, Esq., read a paper on "Knots in Timber;" William Hewit, Esq., read a paper on "Instalments;" and the President, James Sellar, Esq., Architect, gave his closing address, the subject being "The Work of the Section Past and Future."

The thanks of the Section are due to all these gentlemen.

The Annual Business Meeting was held on the evening of Monday, 12th March, when the following gentlemen were elected to office:—

President.—James Sellar, Esq., Architect.

Vice-Presidents.—William Landless, Esq., Architect, and John Cowan, Esq., Wright.

Treasurer.—James Howatt, Esq., Measurer.

Secretary.—A. Lindsay Miller, Architect, 121 West Regent Street.

Members of Council.—David Thomson, Esq., Architect; W. F. Salmon, Esq., Architect; T. L. Watson, Esq., Architect; Campbell Douglass, Esq., Architect; John Honeyman, Esq., Architect; Alexander Muir, Esq., Builder; John Dansken, Esq., Measurer; William Howatt, Esq., Measurer; Robert Scott, Esq., Measurer; Alexander Frew, Esq., Civil Engineer.

A. LINDSAY MILLER, ARCHITECT,
Secretary of Section.

REPORT OF THE BIOLOGICAL SECTION OF THE GLASGOW PHILOSOPHICAL SOCIETY FOR SESSION 1882-83.

The President of the Section delivered an Address at a General Meeting of the Society on 14th March, 1883, the subject being "The Development and Generic Relations of the Carboniferous Corals."

A List of the Office-bearers of the Section will be found at page 557.

D. C. M'VAIL, M.B.

Report of the Sanitary and Social Economy Section of the Glasgow Philosophical Society, Session 1882-3.

The Sanitary and Social Economy Section met for the election of Office-bearers, on the 15th November last, when the following list was unanimously agreed upon:—

Dr. Jas. Christie, *President.*
Mr. Kenneth M. Macleod, } *Vice-Presidents.*
Dr. John Dougall, }
Dr. Eben. Duncan, *Secretary.*

Other Members of Council.

Dr. Fergus.	Mr. Scott.
Mr. Cleland Burns.	Mr. Frew.
Mr. W. R. W. Smith.	Dr. Jas. B. Russell.
Mr. Bromhead.	Mr. W. P. Buchan.
Mr. Dixon.	Dr. Carmichael.
Mr. Hewat.	Bailie Farquhar.

Two papers from the Sanitary Section were read before General Meetings of the Society during the Session—1st, a paper by Dr. Dougall, on "Milk Pollution;" and 2nd, a paper by Dr. Eben. Duncan, on "The Clauses of the Glasgow Police Bill which have reference to the Prevention or Mitigation of Disease."

Several Meetings of the Section were held during the Session, with reference to the remit from the parent society, anent the amendment of the Public Health (Scotland) Act, 1867; and the Report of the Committee appointed last Session was carefully considered. An enlarged Committee was appointed to revise that Report, and consider what further Amendments might be required upon the Health Act in question. The Report of this enlarged Committee was submitted to the Section, and, after careful discussion and amendment, it was adopted. This Report was presented to the Society on the 21st of March. No other business came before this Section during the session.

EBEN. DUNCAN,
Secretary.

Glasgow, April 17th, 1883.

Report of the Chemical Section for Session 1882-83.

During Session 1882-83 this Section held ten General Meetings, at which the average attendance was 17·4. Three gentlemen were elected Associates of the Section in the course of the Session.

The following is a list of the papers contributed to the Section:—

November 6, 1882.—"Recent Progress in the Manufacture of Colors from Coal-tar," by Mr. J. J. Coleman.

November 20, 1882.—Business Meeting. Postponed on account of small attendance.

December 4, 1882.—Postponed Business Meeting. "Siemens' Reverberatory Furnace on the Regenerative Principle, and an Outline of the Siemens-Martin Process," by Mr. Smith.

December 18, 1882.—* "Some Account of the Iron Ore Industry of the North of Spain," by Mr. J. G. Jenkins.

January 22, 1883.—* "On the Use of Litmus, Methyl Orange, Phenacetolin, and Phenolphthaleïn as Indicators," by Mr. R. T. Thomson.

February 5, 1883.—*The President's Annual Address ("The History of some of the Principal Chemical Manufactures in the West of Scotland").

February 19, 1883.—"The History and Reactions of Ozone," by Mr. E. Hunt.

March 5, 1883.—(1) "The Discovery of Phosphorus," by Professor Ferguson, and (2) "The Classification of the Red Resins known as Dragon's Blood," by Dr. Dobbie and Mr. G. G. Henderson.

March 19, 1883.—(1) * "On a Volumetric Process for the Estimation of Nickel and Cobalt," by Dr. Clark. (2) * "On the Use of Rosolic Acid as an Indicator," by Mr. R. T. Thomson.

April 2, 1883.—(1) * "On Algin—a new Glutinous Substance from Sea-weed," by Mr. E. C. C. Stanford. (2) "The Action of Heat and the Chlorides of Phosphorus on the Water-salts of Hypophosphorus, Phosphorus, and Phosphoric Acids," by Dr. Otto Richter.

The papers—six in number—marked with an asterisk (*) were recommended for publication to the Council of the Philosophical Society.

A full report of the discussions, taken by Mr. Cunningham, Shorthand Reporter to the Section, is preserved among the papers of the Section.

(Signed) GEORGE G. HENDERSON,
Hon. Secretary.

STATEMENT OF COST OF BUILDINGS, ADELAIDE PLACE, 207 BATH STREET,

Erected by the Institution of Engineers and Shipbuilders in Scotland and the Philosophical Society of Glasgow.

Paid between 23rd June, 1879, and 31st October, 1882.

JOHN MANN, C.A., *Treasurer to Joint-Committee.*

Class of Work.	Executed by	Classified by Architects thus— I. Work Estimated for.	II. Additional owing to Foundations, &c.	III. Additional Work to that originally Estimated.	IV. Furnishings, &c.	Total.
Mason, ...	Bartley Dinsmore, ...	£1,609 1 2	£261 11 1	£20 14 0	...	£1,891 6 3
Joiner, ...	D. Guthrie & Co., ...	1,013 11 9	44 10 0	187 2 9	£94 15 6	1,340 0 0
Slater, ...	J. Morison & Sons, and others, ...	52 2 7	8 2 9	8 6 5	..	68 11 9
Plasterer, ...	John Craig & Son, ...	291 5 6	...	7 12 0	...	298 17 6
Plumber, ...	William Reid, ...	133 12 6	18 6 0	49 13 0	0 8 6	202 0 0
Cast Iron, ...	Moses M'Culloch & Co., ...	28 5 5	...	...	...	28 5 5
Do., ornamental, . .	Walter M'Farlane & Co., ...	32 12 0	1 18 0	13 0 0	...	47 10 0
Glazier, ...	C. & J. Malloch, ...	60 15 1	...	3 8 9	5 6 2	69 10 0
Stained Glass, ...	Adam & Small, ...	3 5 0	...	59 0 0	...	62 5 0
Gas-fitter, ...	D. & G. Graham, and others, ...	148 11 3	...	34 2 9	44 15 0	227 9 0
Stair Railing, ...	Thomas Philip & Co., ...	30 5 8	...	...	...	30 5 8
Painter, ...	Hugh M'Culloch, ...	92 12 2	...	0 15 0	21 19 10	115 7 0
Smith, ...	M'Kenzie & Bell, and others, ...	16 1 6	...	21 14 6	0 15 0	38 11 0
Heating, ...	Charles Ritchie, ...	100 0 0	...	28 0 0	...	128 0 0
Tiles, ...	Kean & Wardrop, ...	...	...	37 8 6	...	37 8 6
Wire-work, ...	Alexander Cousland, and others, ...	2 7 6	...	3 12 5	...	5 19 11
Turf-laying, ...	Peter Harvey, ...	...	4 0 0	...	...	4 0 0
Ironmongery, ...	William M'Geoch & Co., ...	...	...	...	8 3 0	8 3 0
Furniture, ...	Brown & M'Neil, ...	...	...	...	75 0 0	75 0 0
Do., ...	Alexander & Howell, ...	...	...	...	126 6 9	126 6 9
Do., ...	Brown Brothers, ...	...	...	...	117 15 0	117 15 0
Do., ...	Various, ...	...	...	...	8 19 0	8 19 0
Upholstery, ...	F. & J. Smith, ...	...	...	..	70 12 8	70 12 8
Extincteurs, ...	John Hildesheim, ...	...	...	..	6 11 0	6 11 0
Clocks, ...	Joseph Ruff, and others.	...	...	...	7 0 0	7 0 0
Barometer, &c., ...	James White, ...	...	...	...	7 11 0	7 11 0
Sundries, ...	Various, ...	2 0 0	2 16 5	...	4 17 3½	9 13 8½

Claim of damages by ...	Walter Easton, ...	...	£25 0 0	...	...	£25 0 0
Inspector, ...	John M'Calman, ...	£97 19 0	...	...	..	97 19 0
Watching, ...	Various, ...	74 7 9	...	..	...	74 7 9
Measurer, ...	George Smellie, ...	62 2 6	8 0 0	£8 0 0	...	78 2 6
Architects, ...	T. L. Watson and W. J. Miller, ...	181 0 0	17 0 0	24 0 0	£28 0 0	250 0 0
Treasurer to Committee,	John Mann, ...	...	...	25 0 0	...	25 0 0
Secretary to do.	W. J. Millar, ...	...	...	25 0 0	...	25 0 0
Price of Ground purchased from Adelaide Place Baptist Church, as at Martinmas, 1878, ...		1,200 0 0	...	...	...	1,200 0 0
Conveyancing, ...	Roberton & Ross, &c., ...	91 9 0	...	...	...	91 9 0
Interest on price of Ground till paid, and on Bond till occupation of property, ...		...	...	100 6 5	...	100 6 5
		£5,323 7 4	£391 4 3	£656 16 6	£628 15 8½	£7,000 3 9½

ABSTRACT.

I.—Work estimated for, as per Measurements and Accounts, ...	£5,323	7 4
II.—Additions due to the nature of the foundations and the weather, including extra digging and concrete, with filling in and paving lane; rebuilding washing-house, boundary-walls, and ash-pits of adjoining properties; retaining wall and stair at back of church; also shoring, under-building, and claim of damages, ...	391	4 3
III.—Additional work to that estimated—viz., fire-proof safes, narrow flooring, hot-water supply, ornamental glass tiles, speaking tubes, gate pillar lamps, name-plates gas-regulators, letter-box, back door, glass black boards, fittings in lecture tables, bookshelves, and fittings in Janitor's house, honorariums and interest, ...	656	16 6
IV.—Furniture, linoleum, carpeting, gasaliers, and gas-brackets, moving and repairing bookcases and other furniture, ...	628	15 8½
Total cost, ...	£7,000	3 9½
Whereof the Philosophical Society's one-half is	£3,500	1 11
Contributed, as per Treasurer's Accounts, thus—In Session 1878-79, ... £1,125 0 0		
1879-80, ... 50 0 0		
1880-81, ... 680 0 0		
1881-82, ... 145 1 11		
Society's half of £3,000 Bond over Buildings, ... 1,500 0 0		
	3,500	1 11

MEMO.—The details of the foregoing have been audited on behalf of the PHILOSOPHICAL SOCIETY, by the Auditors of the Society for Sessions 1880-81 and 1881-82; and have also been audited on behalf of the INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Office-bearers of Chemical Section for Session 1882-83.

President.

Mr. Robert R. Tatlock, F.R.S.E., F.I.C., F.C.S.

Permanent Vice-Presidents.

Mr. E. C. C. Stanford, F.C.S.
Dr. W. Wallace, F.R.S.E., F.I.C., F.C.S.
Prof. Ferguson, M.A., F.C.S.
Mr. James Mactear, F.C.S.

Elected Vice-Presidents.

Retires in 1883, - - - Mr. J. J. Coleman, F.I.C.
Retires in 1884, - - - Mr. Alex. Whitelaw.
Retires in 1885, - - - Dr. J. J. Dobbie, M.A., F.C.S.

Treasurer.

Mr. J. J. Coleman.

Secretary.

Mr. G. G. Henderson, B.Sc.

Members of Committee.

Retire in 1883, Mr. Alex. Whitelaw. Mr. J. E. Stoddart. Mr. R. R. Tatlock. Mr. C. Hope.

Retire in 1884, Mr. J. J. Coleman. Mr. G. G. Henderson. Dr. J. J. Dobbie. Mr. James Park.

Retire in 1885, Mr. Jas. Snodgrass, F.C.S. Mr. J. Mayer, F.C.S. Mr. Chrystal. Mr. J. B. Hannay, F.R.S.E., F.C.S.

Geographical and Ethnological Section.

This Section was formed on 11th April, 1883, when the following gentlemen were appointed Office-bearers till the Annual Meeting of the Society, in November, 1883:—

W. G. Blackie, LL.D., F.R.G.S.
James Stevenson, F.R.G.S.
Michael Connal.
Thomas Muir, M.A.
James Grierson.
James Christie, M.D.

Secretary *pro tem.*, James Christie, M.D.,
2 Great Kelvin Terrace, Bank Street, Hillhead.

The following Petition was drawn up by the Committee on the Patent Laws appointed on 25th April, 1883, and was presented to the House of Commons by George Anderson, Esq., M.P.:—

UNTO THE HONOURABLE THE COMMONS OF THE UNITED KINGDOM OF GREAT BRITAIN AND IRELAND, IN PARLIAMENT ASSEMBLED.

THE HUMBLE PETITION OF THE PHILOSOPHICAL SOCIETY OF GLASGOW,

SHEWETH,

That the Philosophical Society of Glasgow, now holding its Eightieth Session, consists of upwards of 600 Members, and represents the Professions, Arts, Manufactures, Trades, and Commerce of the City of Glasgow, and surrounding district.

That the Society has had under consideration the "Patents for Inventions Bill" brought before your Honourable House by the Right Honourable the President of the Board of Trade.

The Society is of opinion that many of the provisions of the Bill are unsatisfactory, and in order that it may more nearly conform to the requirements of Manufacturers, Traders, Inventors, and the public generally, a number of the clauses therein should be amended.

In the opinion of the Society it is not desirable that a Statement of Claims be required to accompany the Provisional Specification. The Inventor is not in a position at this stage to state precisely what part of his Invention he may claim as new. It should suffice that the claim in the Complete Specification be made to cover only the Invention described in the Provisional Specification.

The wording of Clause 12 does not appear to contemplate the possibility of a Patent being lost through delay occurring in the Patent Office.

The Society considers that the operation of the Clause providing for the opening of the Complete Specification to public inspection before the grant of the Patent would be to invite opposition, and to give an unfair advantage to opponents.

The term of Patent Rights proposed in the Bill is, the Society considers, much too short to enable valuable Inventions to be worked with profit, or to induce capitalists to invest in Patents.

A Patentee should be allowed to amend his Specification and Claims, not only by disclaiming such parts as may turn out to be old, but by altering defective claims, or adding claims to cover such parts of his Invention as may have been fairly described, but which, by omission or otherwise, have been left unclaimed in the Original Specification.

It is also of importance that a clearer definition be given than has hitherto obtained of what shall form subject-matter of an Invention.

The Society suggests that the following Amendments be made in the Clauses of the Bill :—

As regards Clause 5, page 2, line 22, by leaving out the words "a Specification, whether provisional or complete," and inserting the words "a Complete Specification."

As regards Clause 9, page 3, by leaving out line 15, and inserting the words "the claims in the Complete Specification are a fair working out of the Invention described in the Provisional Specification;" and in lines 16 and 17, by leaving out the words "that the claims in the two Specifications are not substantially the same," and inserting the words "that the claims in the Complete Specification are not a fair working out of the Invention described in the Provisional Specification."

As regards Clause 10, page 3, lines 29, 30, and 31, by leaving out the words "and the application" to the end of the Clause.

As regards Clause 16, page 5, line 6, by inserting at the end of the Clause the words "and the Provisional and Complete Specifications and Drawings, if any, shall be open to public inspection on and after the date of sealing of Letters Patent."

As regards Clause 17, page 5, line 8, by leaving out the word "fourteen," and inserting the word "seventeen;" in lines 10, 11, and 23, by leaving out the word "seventh," and inserting the word "eighth;" and in line 18, by leaving out the words "may, if he think fit," and inserting the word "shall."

As regards Clause 18, page 6, line 17, by leaving out the words "claimed by," and inserting the words "described in."

As regards Clause 37, page 11, line 14, by adding at the end of the Clause the words "and he shall cause the Provisional and Complete Specifications to be printed with the Drawings of the same dimensions as the filed Drawings."

As regards Clause 43, page 13, line 40, by leaving out the words "Invention" to the end of the Clause, and inserting the words "a Patent may be granted for *(a)* any manner of manufacture; *(b)* any new product or new application of a natural product; *(c)* any machine or any means of producing any manufacture, product, or result; *(d)* any process or method of producing any manufacture, product, or result; *(e)* any part of a machine, means, process, or method of producing any manufacture, product, or result.

And your Petitioners, as in duty bound, shall ever pray.

Signed, in name and on behalf of the Members of the Philosophical Society of Glasgow, by

L. S.

WILLIAM WALLACE, *President.*
JOHN G. M'KENDRICK, *Secretary.*

OFFICE-BEARERS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SESSION 1882-83.

WILLIAM WALLACE, PH.D., F.R.S.E., F.I.C., F.C.S., *President.*

MR. MICHAEL CONNAL,
MR. JAMES MACTEAR, F.C.S.,
JAMES B. RUSSELL, B.A., M.D.
} *Vice-Presidents.*

ALLEN THOMSON, LL.D., D.C.L., M.D., F.R.SS.L. & E.,
PROFESSOR ROBERT GRANT, M.A., LL.D., F.R.S.,
PROFESSOR SIR WM. THOMSON, M.A., LL.D., D.C.L., F.R.SS.L. & E.,
ANDREW FERGUS, M.D., M.R.C.S.Eng.,
} *Honorary Vice-Presidents.*

MR. JOHN ROBERTSON, *Librarian.*

MR. JOHN MANN, C.A., *Treasurer.*

PROFESSOR JOHN GRAY M'KENDRICK, M.D., LL.D., F.R.S.E., F.R.C.P.E., *Secretary.*

MR. JAMES SELLARS, Jun., I.A., Architect, *Architectural Section,*
Mr. JAMES THOMSON, F.G.S., *Biological Section,*
MR. ROBERT R. TATLOCK, F.R.S.E., F.I.C., F.C.S., *Chemical Section,*
JAMES CHRISTIE, M.A., M.D., *Sanitary and Social Economy Section.*
} *Presidents of Sections.*

Other Members of Council.

NEIL CARMICHAEL, M.D., C.M.
MR. NATHANIEL DUNLOP.
MR. JAMES PATON, F.L.S.
MR. ALEXANDER SCOTT.
WILLIAM JAMES FLEMING, M.D.
MR. HAZELTON R. ROBSON.
PROF. WILLIAM JACK, M.A., LL.D.
HENRY MUIRHEAD, M.D.
THOMAS MUIR, M.A., F.R.S.E.
JAMES MORTON, M.D.
JAMES STIRTON, M.D., F.L.S.
MR. ARCHIBALD ROBERTSON.

COMMITTEES APPOINTED BY THE COUNCIL.

COMMITTEE ON FINANCE.

DR. WALLACE, *President.*

MR. NATHANIEL DUNLOP.
PROFESSOR JACK.
MR. JAMES PATON.
MR. ARCHIBALD ROBERTSON.
MR. HAZELTON R. ROBSON.
MR. ALEXANDER SCOTT.

MR. JOHN MANN, *Treasurer, Convener.*
MR. MICHAEL CONNAL, V.-P., *Sub-Convener.*

COMMITTEE ON PAPERS.

DR. WALLACE, *President.*

MR. JAMES MACTEAR,
DR. J. B. RUSSELL,
} *Vice-Presidents.*

DR. NEIL CARMICHAEL.
DR. JAMES CHRISTIE.
MR. MICHAEL CONNAL.
DR. W. J. FLEMING.
DR. JAMES MORTON.
MR. JAMES SELLARS.
DR. JAMES STIRTON.
MR. R. R. TATLOCK.

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Mémoires de Météorologie Dynamique. Par E. Loomis,	The Author.
Sitzungsberichte der Koniglich-Preussischen Akademie der Wissenschaften. 1 to 38. 1882.	The Academy.
Greenwich Observations, 1880,	The Astronomer Royal.
,, Astronomical Results, 1880,	,,
,, Magnetical and Meteorological Observations, 1880,	,,
Report of the Smithsonian Institution, 1880,	The Institution.
Report of the York Meeting of the British Association, 1881,	The Association.
Report of the Southampton Meeting of the British Association, 1882,	,,
Contributions to Meteorology. By E. Loomis,	The Author.
Report of the Sanitary Department for the five years ending 30th April, 1882. By K. M. Macleod,	The Author.
Report of the Royal Society of Tasmania, 1880,	The Society.
Isothermal Lines of the United States, 1871-80,	U.S. War Department.
Proceedings of the Royal Society of Edinburgh, 1880-81,	The Society.
Our Sanitary Laws: How they are Administered. By Dr. Kirkwood, Largs,	The Author.
On the Principles and Practice of Life Assurance. By Archd. Hewat, F.F.A.,	The Author.
Sins against the Laws of Health: Illustrated by the Vital Statistics of the Crosshill District. By Dr. E. Duncan,	The Author.
Some Observations on our present Methods of Disposal of Human Excreta, and their relation to the spread of Epidemic Disease. By Dr. E. Duncan,	The Author.
Fifty Years of Sanitary Legislation in Great Britain, and its Results. By Dr. E. Duncan,	The Author.
List of the Foreign Correspondents of the Smithsonian Institution,	The Institution.
Instructions for Observing the Transit of Venus, 6th December, 1882,	The Washington Observatory.

DONATIONS.	PRESENTED BY
Geological and Geographical Survey of the Territories. VI. 3. By F. V. Hayden, . . .	The Author.
Greenwich Spectroscopic and Photographic Results, 1881, ...	The Astronomer Royal.
On the Dimensions of Cast-iron at various Temperatures, with more especial reference to the Phenomena of the Solid floating on the Molten Metal. By W. J. Millar, . . .	The Author.
First Annual Report of the Bureau of Ethnology to the Secretary of the Smithsonian Institution, 1879-80. By J. W. Powell, ...	The Institution.
Transactions of the North of England Institute of Mining Engineers. Vol. XXXI., . .	The Institute.
Medical Pamphlets of Dr. Andrew Buchanan, .	Mrs. Buchanan.
Transactions of the Institution of Engineers and Shipbuilders in Scotland. Vol. XXV., . .	The Institution.
Notes on the Sand-covered Districts on the East Coast of Aberdeenshire. By William Ferguson,	The Author.
Report on the Mortality Experience of the Australian Mutual Provident Society, 1849-78, .	Mr. Archd. Hewat.
Proceedings of the Natural History Society of Glasgow. Vol. V., 1, ...	The Society.
Quain's Anatomy. Two Vols. 1876, . .	Dr. M'Kendrick.
Klein's Anatomy of the Lymphatic System, 1873,	,,
An Introduction to the Elements of Pharmacy. By F. H. Lescher. 1869, ...	,,
Outlines of Practical Histology. By William Rutherford. 1876, ...	,,
Animal Physiology. By John Cleland, 1874, .	,,
Animal Physiology. By J. G. M'Kendrick. 1876,	,,
A Course of Elementary Practical Physiology, By Foster and Langley. 1876, . . .	,,
Outlines of Physiology for the use of Students. Parts 1 and 2, ...	,,
Jahresberichte über die Fortschnitte der Anatomie und Physiologie. 1872-78. Seven Vols., .	,,
Proceedings of the Perthshire Society of Natural Science. Vol. 1, 2. By Allen Thomson, M.D.	The Society.
Report from the Committee of the Technical College, at the Sydney Mechanics' School of Arts, New South Wales, ...	The Committee.
Memoirs of the Science Department of the University of Tokio. Nos. 6 to 8. 1881, . .	The University.
Transactions of the Seismological Society of Japan. Vol. IV., ...	The Society.
Ventilation of the Guildhall, London, and Report on the Ventilation of the London Custom House. 1882, ...	

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The Sanitary Aspect of Cooking and Heating by Coal Gas. By Dr. Stevenson Macadam. 1882,	The Author.
Monograph of the Central Parts of the Nebula of Orion. By Edward S. Holden. 1882, . .	U.S. Naval Observatory.
Reports upon the U.S. Geographical Surveys West of the 100th Meridian. Vol. III. Supplement—Geology. 1881, . . .	U.S. Government.
Annual Report of the Comptroller of the Currency of the United States. 1881, . .	The Comptroller.
The Calendar of the Pharmaceutical Society of Great Britain. 1883, ...	The Society.
Distribution of Rain over the British Isles during 1873-79. 7 Vols. Compiled by G. J. Symons,	Dr. Muirhead.
Essay on Tobacco. By Henry W. Cleland. 1840, ...	Mr. J. Cleland Burns.
The Peel Banquet. 1837. By James Cleland, LL.D., ...	,,
How the "Mastiff" went to Iceland. By Anthony Trollope. 1878, ...	,,
Journal de l'Ecole Polytechnique. Cahier 51. 1882, ...	L'Ecole Polytechnique.
Catalogue of the Pictures and Sculpture in the Corporation Galleries of Art, Glasgow, 1883, .	Mr. James Paton.
Sketch-Guide to the Italian Art Loan Exhibition, Corporation Galleries, Glasgow, 1882-3, . .	,,
Catalogue of the Glasgow Italian Art Loan Exhibition, 1882-83, ...	,,
Guide to the East Glasgow Loan Exhibition, 1883, ...	,,
The Patent Bills of 1883. Private Aims and Public Claims. By R. A. Macfie, of Dreghorn,	The Author.
Report of the Kelvingrove Museum and the Galleries of Art, Glasgow, 1882, . . .	The Sub-Committee of Parks and Galleries.
Verhandelingen der Koninklijke Akademie van Wetenschappen. Natuurkunde. Dl. 22, .	The Academy.
,, Letterkunde. Dl. 15, .	,,
Verslagen en Mededeelingen, Afd. Natuurkunde, Dl. 17, ...	,,
Verslagen en Mededeelingen, Afd. Letterkunde, Dl. 11, ...	,,
Jaarboek, 1881, ...	,,
Processen-Verbaal, 1881-82, ...	,,
Tria Carmina Latina, ...	,,
Zaakregister. Deel I.—XII., ...	,,
Portugal and the Congo: A Statement. 1883, .	The Author.
Copyright and Patents for Inventions. Vol. II. 1883. By R. A. Macfie, of Dreghorn, . .	The Author.
Report of the Mitchell Library, 1882, . .	The Library Committee.

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Minutes of the Proceedings of the Institute of Civil Engineers. Vol. LXXI. 1883, . .	The Institute.
Origines Celticæ; and other Contributions to the History of Britain. By Edwin Guest, LL.D. 2 Vols., ...	Mrs. Guest.
Manitoba Historical and Scientific Society. 5 Nos., ...	The Society.
The Scientific Transactions of the Royal Dublin Society. Vol. I., Nos. 15-19; Vol. II., No. 2. 1882, ...	The Society.
Proceedings of the Royal Dublin Society. Vol. III., 5. 1882.	,,

BOOKS BOUGHT.

The Revised Theory of Light. By W. Cave Thomas. 1875.
A Manual of the Infusoria. Part VI. By W. Saville Kent. 1882.
Encyclopædia Britannica. Vols. XIV., XV. 1882-83.
Œuvres de Lagrange. Vols. VI., VII. 1873-77.
Œuvres de Laplace. Vol V. 1882.
Wagner's Jahresbericht. 1881.
The Concepts and Theories of Modern Physics. By J. B. Stallo. 1882.
Animal Intelligence. By G. J. Romanes. 1882.
Journal of the Geological Society. Vol. XXXIV., Part 2.
The Zoologist. 1874-5.
Science Gossip. 1873-4.
Association Française. 9me et 10me Sessions. Reims et Alger. 1880-81.
Journal of the Iron and Steel Institute. 1882.
Text-Book of Geology. By Archibald Geikie. 1882.
Disease of Memory. By Th. Ribot. 1882.
The Geological Record. 1878.
Jacobi's Gesammelte Werke. Band 2. 1882.
Life of James Clerk Maxwell. By Lewis Campbell and William Garnett. 1882.
A Popular Sketch of the History of Glasgow. By Andrew Wallace. 1882.
Œuvres d'Augustin Cauchy. Tome I. 1882.
Technological Dictionary in the English and German Languages. Part 1. English-German. 1882.
Political Institutions, being Part 5 of the Principles of Sociology. By Herbert Spencer. 1882.
Man before Metals. By N. Joly. 1883.
Zoological Record. Vol. XVIII. 1881.
Electric Illumination. Vol. I. By James Dredge.
Elementary Rigid Dynamics. By E. J. Routh. 1882.
The International Scientists' Directory. By S. E. Cassino. 1882.
The Science of Politics. By Sheldon Amos. 1883.

An Elementary Treatise on Electricity. By J. Clerk Maxwell. 1881.
Mathematical Papers. By W. Kingdom Clifford. 1882.
Observations on the Construction of Healthy Dwellings—namely Houses, Hospitals, Barracks, Asylums, &c. 1880.
Physics of the Earth's Crust. By Osmond Fisher. 1881.
Elementary Meteorology. By R. H. Scott. 1883.
The Statesman's Year Book. 1883.
L'Année Scientifique et Industrielle. 1883.
Handbook of the Polariscope, and its Practical Applications. By H. Landolt. 1882.
The Scottish Language as illustrating Civilisation in Scotland. By Francesque Michel. 1882.
The Coal and Iron Industries of the United Kingdom. By Rich. Meade. 1882.

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Biblical Archæology,	London.
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Die Deutsche Chemische Gesellschaft,	Berlin.
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Entomological Society of Ontario,	London, Ontario.
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Geological Society of Glasgow,	Glasgow.
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Institution of Mechanical Engineers,	Birmingham.
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National Observatory,	,,
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New York Academy of Sciences,	New York.
New Zealand Institute,	Wellington.
North of England Institute of Mining Engineers,	Newcastle-on-Tyne.
N. Staffordshire Institute of Mining and Mechanical Engineers,	London.
Observatoire Royal de Bruxelles,	Bruxelles.
Odontological Society,	London.

Ohio Mechanics' Institute,	Cincinnati.
Pharmaceutical Society,	London.
Photographic Society,	,,
Philadelphia Alumni Association,	Philadelphia.
Physical Society of London,	London.
Physico-Chemical Society, University of St. Petersburg,	St. Petersburg.
Powys-land Club,	Liverpool.
Publisher of Engineering,	London.
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Royal Irish Academy,	Dublin.
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Royal Society of Edinburgh,	,,
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Seismological Society of Japan,	Tokio.
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Société Royal des Sciences de Liége,	Liége.
Society of Arts,	London.
Society of Engineers,	,,
South Wales Institute of Engineers,	Swansea.
Statistical Society,	London.
United States Geologist,	Washington.
United States Observatory,	,,
United States Survey,	,,
University of Christiania,	Christiania.
University of Tokio, Japan,	Tokio, Japan.
Verein für Erdkunde zu Halle,	Halle.
Videnskabs-Selskabet i Christiania,	Christiania.
Washburn Observatory—University of Wisconsin,	Washburn.

LIST OF PERIODICALS.

WEEKLY.

Academy.
Architect.
Athenæum.
British Architect.
British Medical Journal.
Builder.
Building News.
Chemical News.
Comptes Rendus.
Dingler's Polytechnisches Journal.
Electrician.
Engineer.
Engineering.
English Mechanic.
Iron.
Journal of the Society of Arts.
Journal of Gas Lighting.
Nature.
Notes and Queries.
Pharmaceutical Journal.
Science.
Scientific American.
Telegraphic Journal.

FORTNIGHTLY.

Berichte der Deutschen Chemischen Gesellschaft.
Bulletin de la Société Chimique de Paris.
Journal für Praktische Chemie.

MONTHLY.

American Journal of Science and Arts.
Annales de Chimie et de Physique.
Annales des Ponts et des Chaussées.
Annales des Sciences Naturelles—Botanique.
Annales des Sciences Naturelles—Zoologie.
Annalen der Chemie.
Annalen der Physik und Chemie.
Annals and Magazine of Natural History.
Analyst.
Antiquary.
Beiblätter zu den Annalen der Physik und Chemie.
Bulletin de la Société d'Encouragement.
Bulletin de la Société Géologique de France.
Bulletin Mensuel de l'Observatoire de Montsouris.
Canadian Entomologist.
Chemische Industrie.
Entomologist.
Entomologists' Monthly Magazine.
Journal of the Franklin Institute.
Geological Magazine.
Hardwicke's Science Gossip.
Journal de Pharmacie et de Chimie.
Journal of Botany.
Monthly Notes of the Library Association.
Journal of the Photographic Society.
Journal of Science.
Journal of the Chemical Society.
London, Edinburgh, and Dublin Philosophical Magazine.
Midland Naturalist.
Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Odontological Society's Transactions.
Proceedings of Royal Society of London.
Proceedings of Royal Geographical Society.
Royal Astronomical Society's Monthly Notices.
Sanitary Journal.
Zoologist.

QUARTERLY.

Annales des Mines.
Bulletin de la Société Industrielle de Mulhouse.
Grevillea.
Journal of Anatomy and Physiology.
Journal of the Royal Agricultural Society of England.
Journal of the Scottish Meteorological Society.
Journal of the Statistical Society.
Mind : a Quarterly Review of Psychology and Philosophy.
Quarterly Journal of Geological Society.
Quarterly Journal of Microscopical Science.
Quarterly Journal of Ornithology.
Quarterly Journal of Pure and Applied Mathematics.
Revue Universelle des Mines.
Zeitschrift für Analytische Chemie.

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FOR 1882-83.

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Wilhelm Weber, Göttingen, ... 1860
Ernst Hæckel, Jena, ... 1880

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Joseph Swan, Newcastle-on-Tyne and London, ... 1883
10 E. A. Wünsch, London, ... 1883

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Adam, William, M.A., 34 Garturk street, Govanhill. 1876
Addie, John, 144 St. Vincent street. 1861
Alexander, Jas. W., 49 West Regent street. 1876
Alexander, Thos., 8 Sardinia terrace. 1869
5 Anderson, Alexander, 157 Trongate. 1869
Anderson, David H., Atlantic Mills, Bridgeton. 1875
Anderson, Geo., M.P., Western Club. 1856
Anderson, John, 260 St. Vincent st. 1873
Anderson, J. T., 41 Westbourne gardens. 1881
10 *Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace, 1873
Anderson, W. F. G., 47 Union street. 1878
Armstrong, Wm. J., 3 Royal Exchange court. 1871
Arnot, James Craig, 162 St. Vincent st. 1869
Arrol, Archibald, 16 Dixon street. 1869
15 Arrol, Walter, 16 Dixon street. 1869
Arrol, William A., 16 Dixon street. 1869
Arthur, Wm. Rae, 1 Crown gardens, Dowanhill. 1850

Bain, Sir James, F.R.S.E., 3 Park ter. 1866
Bain, Robert, 22 Dundas street. 1869
20 Baird, Alex. Smith, 26 Sardinia terrace, Hillhead. 1870
Baldie, Robert, I.A., 83 Bath street. 1870
Ball, Henry W., Cranstonhill Engine Works. 1875
Balloch, Robert, 131 St. Vincent st. 1843
Balmain, Thos., 1 Kew terrace, Kelvinside. 1881
25 Barclay, Charles H., 28 Westbourne gardens. 1881
Barclay, James, 36 Windsor terrace. 1872
Barclay, John, 37 Monteith row. 1881
Barlow, John, M.D., Professor of Physiology in Anderson's College. 1880
Baronsfeather, W. N., 7 Berlin terrace, Pollokshields. 1883
30 Barrett, Francis Thornton, Mitchell Library. 1880
Barr, Thos., M.D., F.F.P. & S.G., 10 Albany place. 1879
Bayne, A. Malloch, 1 Hamilton terrace, Partick, 1878
Beatson, George T., B.A. Cantab., M.D., 2 Royal crescent. 1881
*Beith, Gilbert, 19 West Nile street. 1881
35 Bell, Dugald, 27 Lansdowne cres. 1871
Bell, George, F.R.I.B.A., 212 St. Vincent street. 1870
*Bell, Henry, 5 Cornwall terrace, Regent's Park, London, N.W. 1876
Bell, James, 172 Argyle street. 1877
Bell, Robt., M.D., F.F.P.S.G. and Ed., 29 Lynedoch street. 1869
40 Bennet, Alfred R., 134 Douglas st. 1882
Binnie, J., 69 Bath street. 1877
Binnie, Robert, Ashbourne, Gourock. 1881
Black, Adam Elliot, C.A., F.C.S., 13 South Park terrace, Hillhead. 1880
Black, D. A., 214 Bath street. 1880
45 Black, D. Campbell, M.D., M.R.C.S.E., 50 Woodlands road. 1872
Black, J. Albert, 33 Lynedoch st. 1869
Black, John, 16 Park terrace. 1869
Black, Malcolm, M.B., C.M., 5 Canning place. 1880

*Blackie, J. Alexander, 17 Stanhope st. 1881
50 *Blackie, J. Robertson, 17 Stanhope street. 1881
Blackie, Robert, 17 Stanhope st. 1847
Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street. 1841
Blair, G. M'Lellan, 2 Lilybank ter. 1869
Blair, J. M'Lellan, 8 Cecil place, Paisley road. 1869
55 Blyth, James, M.A., F.R.S.E., Professor of Mathematics and Natural Philosophy in Anderson's College. 1881
Bost, Timothy, 33 Renfield street. 1876
Bottomley, James T., M.A., F.R.S.E., F.C.S., Demonstrator in Natural Philosophy, University of Glasgow, 2 Eton terrace, Hillhead. 1880
Bottomley, Wm., Junr., C.E., University. 1880
Boucher, J., I.A., 247 St. Vincent st. 1870
60 Bowie, Campbell T., 26 Bothwell st. 1870
Boyd, John, Shettleston Iron Works, near Glasgow. 1873
Boyd, Wm., Blythswood Foundry, 61 North street. 1852
Brand, James, C.E., 172 Buchanan street. 1880
Brodie, John Ewan, M.D., C.M., F.F.P.S.G., 1 Albany place. 1873
65 Bromhead, Horatio K., I.A., A.R.I.B.A., 245 St. Vincent st. 1870
Brown, James, 76 St. Vincent st. 1876
Brown, John, 22 Renfield street. 1879
Brown, John C., 149 W. George st. 1880
*Brown, John, 11 Somerset place. 1881
70 Brown, Nicol, 36 Canonbury park, London, N. 1869
Brown, Richard, Strone Colliery Co., 49 W. George street. 1855
Brown, Robert, 19 Jamaica street. 1882
Brownlee, J., 23 Burnbank gardens. 1860
Brownlie, Archibald, Bank of Scotland, Barrhead. 1880
75 Brownlie, Jas., Victoria Saw Mills. 1877
Brownlie, John, 2 Oakley terrace. 1874
Bruce, John Inglis, Helen street, Govan. 1869
Bruce, John L., I.A., 103 West Regent st. 1873
Bryce, David, 129 Buchanan street. 1872
80 Bryden, Robt. A., F.R.I.B.A., 15 Dalhousie street. 1870
Buchan, Wm. P., S.E., 21 Renfrew street. 1875
Buchanan, Alex. M., M.A., M.D., Professor of Anatomy in Anderson's College, 98 St. George's rd. 1876
Buchanan, G. Millar, 121 Kennedy st. 1881
Buchanan, George, A.M., M.D., Professor of Clinical Surgery in the University of Glasgow, 193 Bath street. 187
85 Buchanan, Geo. S., 95 Candleriggs. 1845
Buchanan, William L., 212 St. Vincent street. 1873
Buchanan, William, 10 Carrington street, West. 1881
Burnet, John, I.A., 167 St. Vincent street. 1850
Burnet, Lindsay, Assoc. M.I.C.E., St. Kilda, Dowanhill. 1882
90 Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864
Burns, J. Cleland, Ferntower, Crieff. 1874

Cameron, Charles, M.D., LL.D., M.P., 104 Union street. 1870
Cameron, H. C., M.D., 27 Elmbank crescent. 1873
Cameron, R., 123 St. Vincent st. 1873
95 Campbell, J. A., LL.D., M.P., 137 Ingram street 1848
Campbell, John D., Merroughsdale cottage, Copeland road, Govan. 1858
*Campbell, Louis, 3 Eton terrace, Hillhead. 1881
Campbell, William, 128 Ingram st. 1880
Carlile, Thomas, 27 St. Vincent pl. 1851
100 Carlton, Charles, 141 St. Vincent st. 1870
Carmichael, Neil, M.D., C.M., 29 S. Cumberland street. 1873
Carmichael, Thomas, Mount Hope, Bridge of Allan. 1879
Carrick, John, I.A., City Architect, 74 Hutcheson street. 1846
Cassels, Robert, 168 St. Vincent st. 1858
105 Cassells, J. P., M.D., 2 Newton ter. 1874
Cherrie, James M., Clutha cottage, Tollcross. 1876
Christie, James, A.M., M.D., F.F.P.S.G., 2 Great Kelvin terrace, Bank street, Hillhead. 1876
Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
Chrystal, W. J., Shawfield Works, Rutherglen. 1880
110 Church, James, 88 Renfield street. 1867
Church, Wm., Jun., 45 West Nile street. 1855
Church, W. R. M., C.A., 45 West Nile street. 1882
Clapperton, John, 5 Sandyford pl. 1874
*Clark, G. W., Dumbreck house. 1877
115 Clark, Henry E., L.R.C.S. Eng., 24 India street. 1876
Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
Clark, John, 9 Wilton crescent. 1872
*Clark, William, Mile-end. 1876
Clavering, Thos., 30 Gordon street. 1856
120 Cleland, A. B. Dick, Kilrock, Bridge of Allan. 1871
Clinkskill, James, 1 Holland place. 1868
Clouston, Peter, 1 Park terrace. 1861

Coats, Joseph, M.D., 7 Elmbank crescent. 1873
*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
Coghill, Wm. C., 263 Argyle street. 1873
Coleman, J. J., F.C.S., 45 West Nile street. 1869
Collins, Sir Wm., 3 Park ter., East. 1869
Collins, Wm., Jun., Huntly gardens. 1879
Colquhoun, Jas., 158 St. Vincent street. 1876
Combe, George Jones, 49 Montrose street. 1877
Combe, William, 90 Regent terrace, Stirling road. 1877
Connal, Michael, Virginia buildings, *Vice-President*. 1848
Connell, James, 182 Crookston st. 1870
Connell, Wm., 38 St. Enoch square. 1870
Copeland, Jas., 1 Thornville terrace, Hillhead. 1869
Copland, Wm. R., M. Inst. C.E., 146 West Regent street. 1876
Coubrough, A. Sykes, Blanefield, Strathblane. 1869
Couper, James, Craigforth House, Stirling. 1862
Couper, James, 37 Lansdowne cres. 1878
Couper, Wm., 9 Huntly gardens, Hillhead. 1873
Cowan, John, 12 Ure place. 1870
Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
Cranston, George, Jun., 425 Sauchiehall street. 1880
Crawford, David, Jun., 5 Beechwood place, Dalmarnock road. 1873
Crawford, W. B., 104 West Regent street. 1872
Cree, Thomas S., 17 Exchange sq. 1869
Cross, David, 25 Park circus. 1850
Cunningham, John M., Clydesdale Bank. 1881
Cunningham, J. R., Jun., 4 Derby crescent, Kelvinside. 1881
Curphey, Wm. Salvador, 5 Broomhill drive, Partick. 1883
*Cuthbertson, John N., 29 Bath st. 1850

Dansken, A. B., 179 West George street. 1877
*Dansken, John, 121 W. Regent st. 1876
Darling, Geo. E., 178 St. Vincent street. 1870
Davidson, T., Jun., 33 Garngadhill. 1872
Day, St. John Vincent, C.E., F.R.S.E., 115 St. Vincent street. 1866
Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
Dempster, John, 33 Abbotsford pl. 1875
Dennison, Wm., C.E., 175 Hope street. 1876
Dewar, Duncan, Kirkhill, Cambuslang. 1877
Dickie, James, Broomfield, Stanmore, Middlesex. 1879
Dickson, James, 15 Binnie place. 1871
Dittmar, W., F.R.SS., L. & E., Professor of Chemistry, Anderson's College. 1875
Dixon, A. Dow, 10 Montgomerie crescent, Hillhead. 1873
Dixon, Edward M., B.Sc., 11 Hopetoun place. 1860
Dixon, Peter W., 19 Elmbank cres. 1871
Dobbie, James Johnston, M.A., D.Sc., Assistant to the Professor of Chemistry, University, 292 St. Vincent street. 1880
Donald, John, Dennistoun Public School. 1872
Donald, William J. A., 27 St. Vincent place. 1877
Donald, Alex. W., Bank place, Cambuslang. 1880
Dougall, Franc Gibb, 167 Canning street. 1875
Dougall, John, M.D., F.F.P.S., Lecturer on Materia Medica in the Glasgow Royal Infirmary School of Medicine, 6 Belmar terrace, Shields road, Pollokshields. 1876
Douglas, Campbell, I.A., 266 St. Vincent street. 1870
Downie, James, North Bank house, Kirkintilloch. 1872
Downie, Robert, Jun., Carntyne Dye-works, Parkhead. 1872
Drew, Alex., 149 West George st. 1869
Dryburgh, Jas. N., Minerva cottage, Holmhead, Cathcart. 1872
Duff, M. Campbell, 145 St. Vincent street. 1880
Duncan, Alex., B.A., 242 St. Vincent street. 1878
Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873
Duncan, Robert, Engineer, Partick Foundry. 1875
*Duncan, Walter, 9 Montgomerie cres. 1881
*Dunlop, Nathaniel, 1 Montgomerie crescent, Great Western road. 1870
Dunn, John S., Rockvilla Saw Mills, Port-Dundas. 1876
Dunn, Robert Hunter, 4 Belmont crescent. 1878

Easton, Robert, C.A., 115 Buchanan street. 1880
Easton, Walter, 32 Exchange sq. 1878
Easton, William J., 150 West Regent street. 1876
Edward, David, 92 Buchanan st. 1878

Elder, James, C.E., 204 St. Vincent street. 1881

Fairlie, Colin B., C.E., 67 Renfield street. 1874
Fairweather, Wallace, C.E., 96 Buchanan street. 1880
Falconer, Patrick, 33 Hayburn crescent, Partick. 1876
Falconer, Thos., 50 Kelvingrove st. 1880
Farquhar, John, 13 Belhaven terrace. 1872
Fawsitt, Charles A., 4 Maule terrace, Partick. 1879
Fergus, And., M.D., M.R.C.S.Eng., 3 Elmbank crescent, *Hon. Vice-President.* 1868
Fergus, Jas., 5 Burnbank gardens. 1880
Ferguson, John, M.A., Professor of Chemistry, University of Glasgow. 1869
Ferguson, Peter, 4 Linwood ter., Glasgow st., Hillhead. 1866
Ferguson, Thomas, Westmuir st., Parkhead. 1883
Fergusson, Alex. A., 48 M'Alpine st. 1847
Fife, William, 52 Glassford street. 1880
Finlay, Joseph, 9 Montgomerie drive, Kelvinside. 1873
Finlay, John, Moss Park, Albert road, Pollokshields. 1850
Finlay, Robert Gilchrist, Jun., Holmfield, Dalmuir. 1881
Finlayson, Jas., M.D., 351 Bath st. 1873
*Fleming, James, 7 Fitzroy place. 1880
*Fleming, William James, M.D., 155 Bath street. 1876
Forbes, Alex., Undercliffe cottage, Wemyss Bay. 1879
Foulds, John, L.D.S., 173 Bath st. 1877
Foulis, William, C.E., 42 Virginia street. 1870
*Fowler, John, Kelvinbank terrace, Sandyford. 1880
Frame, Thomas, Royal Bank place. 1863
Frazer, Daniel, 113 Buchanan st. 1853
Frew, Alex., C.E., 175 Hope street. 1876
Frew, Robert, M.E., 75 Bath street. 1874
Fulton, David, Duke Street Engraving Works, 24 Ark lane. 1872

Gairdner, W. T., M.D., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863
Galbraith, Andrew, 123 Hope st. 1857
Galbraith, William, 3 Blythswood square. 1868
Gale, Jas. M., C.E., Water Office, 23 Miller street. 1856
Galloway, T. Lindsay, C.E., Plantation quay, West. 1881
Gardner, Daniel, 36 Jamaica street. 1869
Garroway, John, 58 Buchanan st. 1875
Garroway, Robt., M.D., Rosemount, Cumbernauld road. 1859
Geddes, Wm., Battlefield, Langside. 1846
Gibb, Peter, 10 Granby terrace. 1883
Gillespie, Edward, Chapel Croft, Cambuslang. 1882
Gillies, Wm., Battlefield, Langside. 1869
Gillies, W. D., 96 Miller street. 1872
Gilmour, J. B., 50 North Hanover street. 1865
Gilfillan, Wm., 129 St. Vincent st. 1881
Glaister, John, M.B., 16 Grafton square. 1879
Goodwin, Robert, 58 Renfield st. 1875
Gorman, William, 153 West Nile st. 1860
Gossman, Adam, 79 Robertson st. 1870
Gourlay, John, C.A., 24 George square. 1874
Gourlay, Robert, Kirklee avenue, Great Western road. 1869
Gow, Alexander, 117 Ladbroke Grove Road, Notting hill, London, W. 1869
Gow, Robert, Cairndowan, Dowanhill gardens. 1860
Graham, David, Jun., 140 Douglas street. 1876
Grant, Robt., M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow, Observatory, *Hon. Vice-President.* 1860
Grant, Charles, 160 Hope street. 1883
Gray, James, M.D., 15 Newton terrace. 1863
Gray, James, 7 Knowe ter., Pollokshields. 1876
Greenlees, Alex., M.D., 405 St. Vincent street. 1864
Grierson, James, 5 Belhaven cres., Kelvinside. 1880
Grieve, John, M.D., care of W. L. Buchanan, 212 St. Vincent st. 1856
Grieve, Robert, L.R.C.S., Ed., 52 Holmhead street. 1872

Hamilton, Geo., 149 St. Vincent st. 1871
Hamilton, J. Struthers, 8 Regent Park terrace, Queen's Park. 1869
Hamilton, Patrick, 149 St. Vincent street. 1854
Hamilton, David C., 21 Carlton place. 1880
Hannay, Anthony, 23 Exchange square. 1856
Hannay, Jas. B., F.R.S.E., F.C.S., Annfield Chemical Works, Sword street. 1879
Hannay, Thos., 166 Buchanan st. 1864
Hannay, Maxwell, 104 West George street. 1881
*Harvie, John, Secretary, Clydesdale Bank, 30 St. Vincent place. 1880

Hay, John, 12 Terrace street. 1870
*Henderson, John, Jun., 4 Crown terrace, Dowanhill. 1879
Henderson, Thos. Brown, M.D., 17 Elmbank crescent. 1880
Henderson, Thos., 47 Union street. 1855
Henderson, Wm., 13 Annfield terrace, Partickhill. 1853
Henderson, Wm., 15 Cadogan st. 1873
*Henderson, A. P., 10 Crown terrace, Dowanhill. 1880
Henry, R. W., 10 Garthland st. 1875
Hewat, Arch., F.F.A., F.S.S., 122 St. Vincent street. 1877
Heys, Zechariah J., South Arthurlie, Barrhead. 1870
Higginbotham, James S., Springfield court, Queen street. 1874
Higgins, Henry, Jun., 252 West George street. 1878
Hill, Andrew, 22 Arlington street. 1877
Hodge, William, 15 Hillsborough square, Hillhead. 1878
Hoey, David G., 124 St. Vincent st. 1869
Hogg, Robert, Inglisby villa, Pollokshields. 1865
Holt, T. G., 25 Wellington street. 1875
Honeyman, John, F.R.I.B.A., 140 Bath street. 1870
Horne, R. R., C.E., 150 Hope st. 1876
Howatt, James, 146 Buchanan st. 1870
Howatt, William, 146 Buchanan street. 1870
Hunt, Edmund, 87 St. Vincent street. 1856
*Hunt, John, Milton of Campsie, 1881
Hunter, James, Newmains house, Motherwell. 1854
Hunter, James, 156 St. Vincent street. 1874
Hutton, W. R., 4 Bath street. 1868

Inglis, Anthony, 64 Warroch street. 1854
Inglis, John, 64 Warroch street. 1850

*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
Jamieson, And., C.E., Principal of College of Science and Arts. 1881
Jamieson, John L. K., 9 Crown ter., Dowanhill. 1868
Johnstone, Jas., Coatbridge street, Port-Dundas. 1866

Kennedy, Hugh, Redclyffe, Partick. 1876
Kennedy, Thos., 146 Ingram street. 1869
Kennedy, Walter Stewart, Allanbank, Crosshill. 1873
Kennedy, William, St. Margaret's, Newark Drive, Pollokshields. 1882
*Ker, William, 1 Windsor terrace, West. 1874
Kerr, Charles James, Greenfaulds house, Cumbernauld. 1877
Kerr, James Hy., 13 Virginia st. 1872
Kerr, John G., M.A., Prospect Avenue, Cambuslang. 1878
Key, William, Tradeston Gas-works. 1877
King, James, 57 Hamilton drive, Hillhead. 1848
King, James, of Levernholm, 115 Wellington street. 1855
Kirk, Alexander C., 19 Athole gardens, Dowanhill. 1869
Kirk, Robert, M.D., Newton cottage, Partick. 1877
Kirkpatrick, Andrew J., 10 Woodside place. 1869
Kirkwood, Anderson, LL.D., 7 Melville terrace, Stirling. 1869
Kirsop, John, 98 Argyle street. 1855
Knox, Adam, 47 Crownpoint road. 1881
Knox, John, 129 West George street. 1870
Knox, John, 25 Bath street. 1883

Laidlaw, David, Chaseley, Skelmorlie. 1879
Laird, Geo., 10 Ann st., Bridgeton. 1870
Laird, George H., 137 Greenhead street. 1882
Laird, John, Marchmont, Port-Glasgow. 1876
Laird, John, Royal Exchange Sale Rooms. 1879
Lamb, Thomas, 220 Parliamentary road. 1870
Lang, William, Jun., Crosspark, Partick. 1865
Leggatt, Robert, 38 Sauchiehall street. 1869
Latta, James, 8 Miller street. 1869
Latta, John, 138 W. George street. 1880
Lawson, John, Cranstonhill. 1880
Leisler, Louis, 21 St. Vincent place. 1869
Lindsay, Archd. M., M.A., 87 West Regent street. 1872
Lindsay, Wm. G., 157 St. Vincent street. 1871
Livingston, Robert, 263B Argyle street. 1879
*Long, John Jex, 8 Whitevale. 1862
Lothian, J. Alexander, M.D., L.R.C.S.E., 6 Newton terrace. 1872
Low, James, 176 St. Vincent st. 1878

M'Alley, Robert, Chemical Works, Falkirk. 1872
M'Andrew, John, 17 Park st., East. 1843
Macarthur, J. G., 7 West Prince's street. 1874

M'Call, J., F.R.C.V.S., Prof. of Veterinary Medicine and Surgery, Veterinary College, 85 Buccleuch street. 1866
Maccall, Samuel, 16 Hillsborough square, Hillhead. 1882
M'Callum, George, Rossbank, Cambuslang. 1850
335 M'Clure, David, 62 Argyle street. 1880
M'Conville, John, M.D., 11 Elmbank crescent. 1870
M'Crae, John, 47 Kersland terrace, Hillhead. 1876
M'Creath, James, M.E., 95 Bath street. 1874
M'Culloch, William, 50 Westbourne gardens, West. 1872
340 M'Culloch, Hugh, 231 St. George's road. 1880
Macdonald, Arch. G., 8 Park circus. 1869
Macdonald, Thomas, 109 Bath st. 1869
M'Ewan, Wm., Jun., 17 St. Vincent lane. 1869
M'Farlane, Graham Jas., Elderslie. 1882
345 Macfarlane, Samuel, Meadowbank, Torrance of Campsie. 1876
Macfarlane, Walter, Saracen Foundry, Possil Park. 1855
M'Farlane, Walter, Printworks, Thornliebank. 1869
M'Gill, J. S., 8 Montgomerie Quadrant. 1869
M'Gillivray, James P., 112 Bath street. 1883
350 M'Gilvray, R. A., 129 West Regent street. 1880
M'Gregor, Duncan, F.R.G.S., 45 Clyde place. 1867
M'Gregor, Jas. W., 4 Gt. Western terrace, Hillhead. 1869
M'Gregor, James, 1 East India avenue, London, E.C. 1872
M'Grigor, Alexander B., LL.D., 172 St. Vincent street. 1857
355*M'Ilwraith, James, 4 Westbourne terrace, Kelvinside. 1872
M'Intyre, Peter, 132 Ingram street. 1873
Mackay, John, Jun., 28 Jamaica street. 1869
*M'Kenzie, W. J., Oakfield terrace, Hillhead. 1879
*M'Kenzie, W. D., 43 Howard st. 1875
360 M'Kendrick, John G., M.D., LL.D., C.M., F.R.C.P.E., F.R.S.E., Professor of Institutes of Medicine in the University of Glasgow, Fullerian Professor of Physiology in the Royal Institution of Great Britain, 33 Westbourne gardens, *Secretary.* 1877
Mackinlay, David, 6 Great Western terrace, Hillhead. 1855
M'Kissack, John, 234 W. George street. 1881
M'Laren, Robert, Canal street, Port-Eglinton. 1848
M'Laren, William Ed., 13 Exchange place. 1873
365*Maclay, David T., 169 W. George street. 1879
Maclean, A. H., 124 Queen street. 1870
Maclehose, James, 18 Victoria cres., Dowanhill. 1867
Maclehose, James J., M.A., 61 St. Vincent street. 1882
M'Lellan, John Young, Blackhill house, Cumbernauld road. 1882
370 M'Lellan, Lewis, 7 Belhaven ter. 1869
M'Lellan, Walter, 129 Trongate. 1856
M'Leod, Kenneth M., 1 Montrose street. 1870
Macmillan, Daniel, F.E.I.S., 26 Ashton terrace. 1882
M'Nab, John, 79 West Nile street. 1881
375 M'Naughton, Duncan, 91 Hamilton drive, Hillhead. 1883
M'Nicol, Peter, M.A., 14 Derby terrace. 1873
M'Onie, Andrew, Scotland street, Tradeston. 1860
Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
M'Pherson, George L., 26 Albert road, Crosshill. 1872
380 Mactear, James, F.C.S., St. Rollox Chemical Works. 1867
M'Vail, D. C., M.B., 3 St. James' terrace, Hillhead. 1873
Maddever, John C., Sen., M.D., 19 Battery place, Rothesay. 1881
Main, James, A. R., 25 Hope st. 1870
Manford, Stuart, 18 St. James' ter., Hillhead. 1874
385 Mann, John, C.A., 154 St. Vincent street, *Treasurer.* 1856
Manwell, James, 4 Albert road, Pollokshields. 1876
Martin, Thomas, 166 Sauchiehall street. 1862
Martin, Thos., 19 Rupert st., Great Western road. 1871
Marwick, J. D., LL.D., F.R.S.E., Killermont House, Maryhill. 1878
390*Mason, Stephen, 24 Belhaven ter. 1870
Mathieson, John A., 14 Sardinia terrace, Hillhead. 1851
Mathieson, Thomas A., 13 East Campbell street. 1869
Mayer, John, F.C.S., 2 Clarinda terrace, Pollokshields. 1860
Mechan, Arthur, 36 Elliot street. 1876
395 Mechan, Henry, 36 Elliot street. 1879
Menzies, Thos., Hutchesons' Grammar School, Crown street. 1859

Michaelson, M., 5 Woodside place. 1878
Middleton, Robert T., M.P., 179 West George street. 1800
Millar, James, 158 Parliamentary road. 1870
Millar, William, 3 Woodside ter. 1873
Miller, A. Lindsay, 121 W. Regent street. 1878
Miller, Daniel, C.E., 203 St. Vincent street. 1851
*Miller, George, 1 Westbourne gar. 1881
Miller, Hugh, M.D., F.F.P.S., 298 Bath street. 1872
Miller, James, 21 Woodside place. 1869
Miller, John (Messrs. James Black & Co.), 23 Royal Exchange sq. 1874
Miller, Thomas, Myrtle park. 1876
Miller, Thos., 138 Wellington st. 1882
Miller, Thos. P., Cambuslang Dye-works. 1864
Miller, W. M., 5 Shaftesbury ter., West Regent street. 1867
Mills, Edmund J., D.Sc., F.R.S., Anderson's College. 1875
Milne, William, M.A., B.Sc., High School. 1881
Mirrlees, James B., 45 Scotland street, Tradeston. 1869
Mitchell, Jas. L., 10 Gt Western terrace. 1878
Mitchell, Robert, 12 Wilson street, Hillhead. 1870
Moffatt, Alexander, 47 Union st. 1874
Montereau, Emile Louis de, 107 Pollok street. 1877
Moore, Alexander, C.A., 128 Hope street. 1869
Moore, Robert H., 141 Onslow drive. 1876
Moore, William, M.E., 3 Florentine terrace, Hillhead. 1860
Morgan, Andrew Henderson, 157 West George street. 1881
Morgan, John, Springfield house, Bishopbriggs. 1844
Morrice, Alexander, Tullymet, Ayton road, Pollokshields. 1873
Morrice, Jas. A., Tullymet, Aytoun road, Pollokshields. 1883
Morrison, Donald, LL.D., 4 Victoria terrace, Dowanhill. 1877
Morrison, James, 98 Sauchiehall st. 1869
Morton, James, M.D., Professor of Materia Medica in Anderson's College, 199 Bath street. 1868
Morton, James, Turkey-red Works, Dalquhurn, Renton, 1876
Mossman, John, 21 Elmbank cres. 1870
Mowat, John, 13 Montgomerie crescent, Kelvinside. 1881
Muir, Alex., 65 Eglinton street. 1883
Muir, Alex. G., 6 Regent park terrace, Strathbungo. 1882
Muir, Allan, 36 George street. 1881
Muir, John, 6 Park gardens. 1876
Muir, Thomas, M.A., F.R.S.E., Beechcroft, Bishopton, *Vice-President.* 1874
Muir, Wm. Woodneuk, Barrhead. 1882
Muir, William R., 345 Bath cres. 1877
*Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873
*Muirhead, Henry, M.D., Bushy Hill, Cambuslang, *Vice-President.* 1869
*Muirhead, Robt. Franklin, B.Sc., 189 Renfrew street. 1879
Munro, Daniel, 7 Park quadrant. 1867
Munsie, George, 1 St. John's ter., Hillhead. 1871
Murdoch, James, Glenneuk, Port-Glasgow. 1857
Murdoch, Jas. B., Hamilton place, Langside. 1855
Murdoch, Robert, 16 Main street, Gorbals. 1880
Murdoch, Wm., 30 Hope street. 1879
*Murray, David, 169 West George street. 1876
Murray, A. Erskine, Sheriff-Substitute of Lanarkshire, Sundown, Montgomerie drive. 1881
Milligan, W. J., Laurel bank, Partick. 1881

Napier, James, F.C.S., F.R.S.E., Maryfield, Bothwell. 1849
Napier, James, Jun., Maryfield, Bothwell. 1870
*Napier, John, 23 Portman square, London. 1849
Neilson, Walter, 172 West George street. 1856
Neilson, Walter M., Queenshill, Ringford, Kirkcudbrightshire. 1843
Neilson, Wm., 307 St. Vincent st. 1871
Nelson, Alex., 8 Prince's square. 1880
Nelson, D. M., 11 Bothwell street. 1875
Newman, David, M.B., C.M., Pathologist, Royal Infirmary, 18 Woodside place, W. 1877
Nicol, David, Roxburgh villa, Bothwell. 1872
Nicol, James, City Chambers, 1872
Nowery, William, 37 Derby street. 1876

O'Beirne, William, Chemical works, Clydebank. 1881
Ogilvie, Thomas Robertson, F.C.S., 13 Forsyth street, Greenock. 1875
Ogilvie, William, 1 Doune terrace. 1881
Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870
Outram, D. E., 16 Grosvenor ter., Hillhead. 1878

Paris, Wm., Glasgow Iron Works, St. Rollox. 1869
Paris, William, Jun., Glasgow Iron Works. 1869
Park, James, Millburn Chemical Works. 1877
470 *Parnie, James, 32 Lynedoch street. 1874
Paterson, Jas. A., 51 Apsley place. 1882
Paterson, Robert, C.A., 28 Renfield street. 1881
Paton, Jas., F.L.S., Corporation Galleries, and Kelvingrove Museum. 1876
Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873
475 Pearce, William, 10 Park terrace. 1881
Pennycook, C. H., 2 Chatham place, Stirling road. 1869
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485 *Provan, James, 40 West Nile st. 1868
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530 Russell, Thomas, Cleveden, Kelvinside gardens. 1870

Salmon, James, F.R.I.B.A., 197 St. Vincent street. 1870
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535 Schmidt, Alfred, 382 New City road. 1881
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Sim, William, Custom House quay. 1862
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Simpson, P. A., M.A. Cantab., M.D., Regius Professor of Forensic Medicine, University, 1 Blythswood sq. 1881
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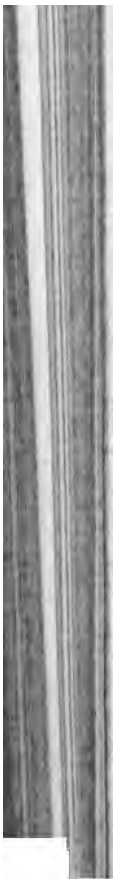

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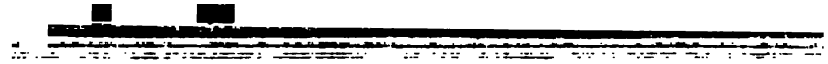

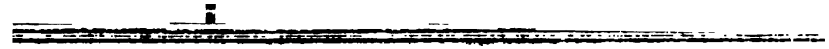

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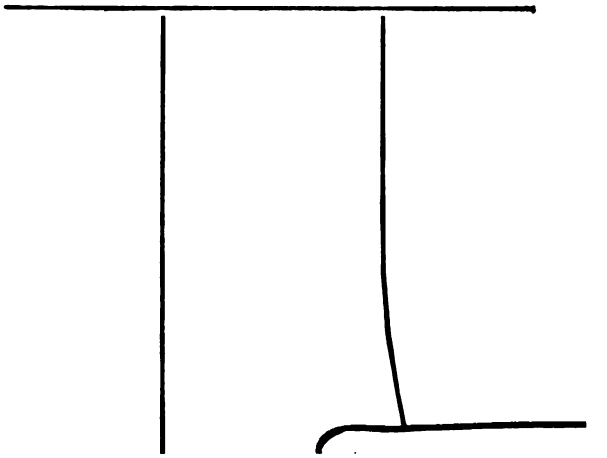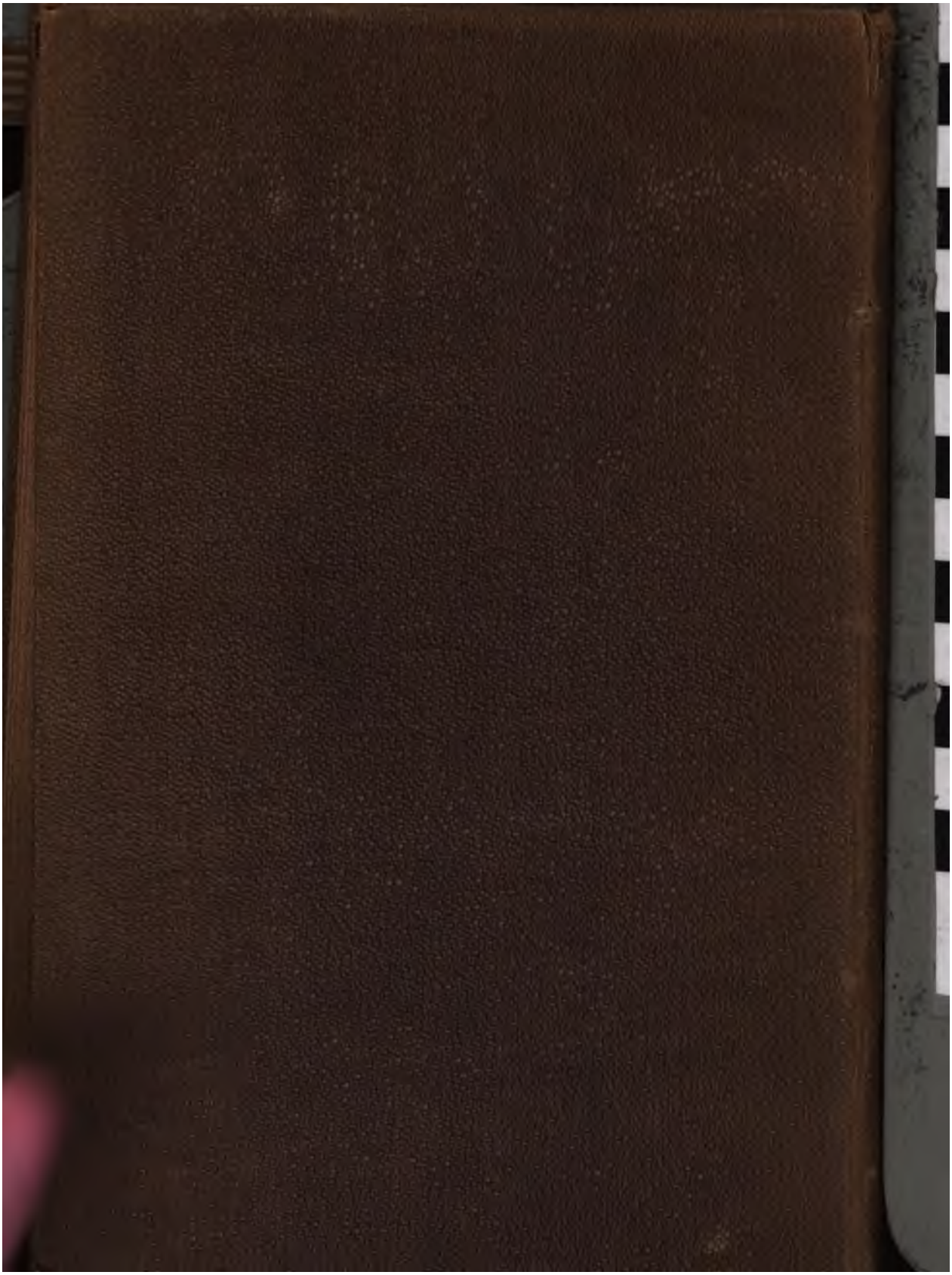
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